o 1944

HEATING AND VENTILATING

MERCIAL, INDUSTRIAL AND INSTITUTIONAL AIR CONDITIONING, REFRIGERATION, PIPING, HEATING, VENTILATION

Large paint spray room for COMMANDO planes requires special ventilation and heating. See article on page 53.

Heating 3200 Gallons of Juice from 70° to 210° *in 7 minutes flat*

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A MONTHLY
MAGAZINE FOR ENGINEERS
AND CONTRACTORS CONCERNED WITH
COMMERCIAL, INDUSTRIAL AND INSTITUTIONAL AIR CONDITIONING, REFRIGERATION, PIPING, HEATING, VENTILATION

HEATING AND VENTILATING

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CONTENTS FOR MAY, 1944

VOLUME 41 NUMBER 5

Detinning Plant Uses 20,000 Feet Pipe 41
C. P. Stolberg

Direct Fired Heaters for Dehydration 43

Evaporative Cooling by Towers and Spray Ponds 44
T. W. Reynolds

Army Cooking and Heating Units 48

Refrigeration Retards Age Hardening of Aluminum Alloys 49
F. Keller

New Bidding Practice for Building Materials 52

Curtiss Commandos 53
H. W. Tompkins

Blueprint of Post-War Realities—Air Sanitation 57
J. M. Dalla Valle

Studies of Exposure to Dust and Fumes 72

Health Hazards Associated with Welding 73
F. W. Hutchinson

Aye, There's The Rub! 77
John J. Woolfenden

Washington News 78
Loring F. Overman

Reference Data 269-270 80

News of Equipment and Materials 82

Degree-Days for March, 1944 84

News of the Month 88

Reviews of Technical Publications 94

New Catalogs 95

Getting Personal 97

With the Manufacturers 98

Personals and Personnel 99

Industrial Degree-Days for March, 1944 100

Army-Navy "E" Awards 100

Coming Events 100

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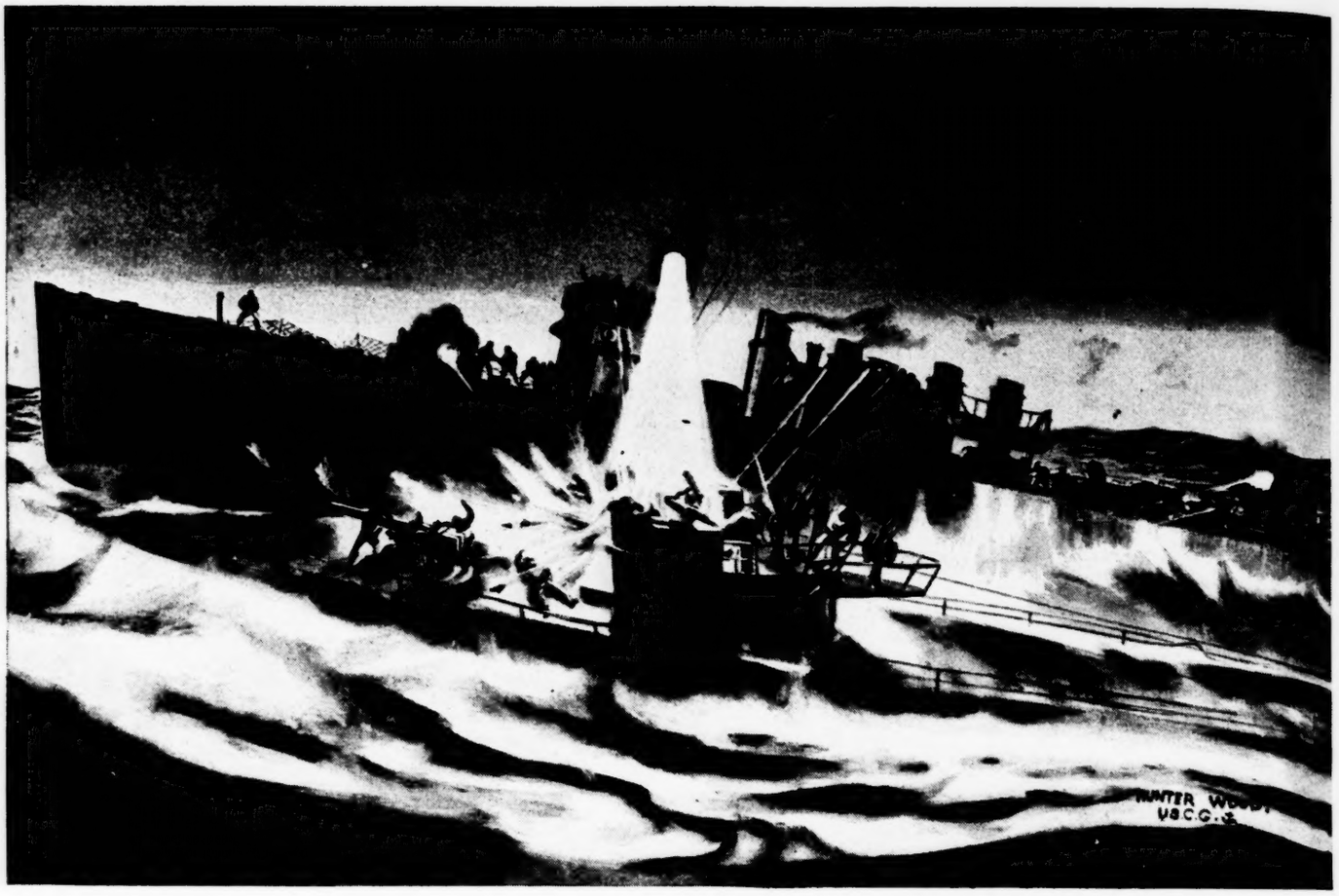
NEXT MONTH'S ISSUE

Dwindling coal piles have focused attention on the importance of coal in our industrial and private lives. Getting the most out of coal has become an important issue. That is why attention is directed to the timely blueprint series subject by Irwin R. Hoffman on "Coal for Heating and Steam Generation," in the June issue.



Official U. S. Navy photograph of Coast Guard Combat Artist Hunter Wood's drawing of USS Borie in one of the most dramatic actions in the Battle of the Atlantic.

Steam You Saved Helped Sink This Sub

You may be at your desk figuring ways and means to save steam in order to conserve fuel, but you're somewhere else, too. You're in there fighting on the high seas! *You are*—IF! If you really saved, *and keep on saving* heating steam to conserve fuel.

Soldiers can't fight if ammunition and food doesn't reach them. Planes can't fly and mechanized forces can't move without the power supplied by fuel. The ships that carry vital supplies would stay at anchor in home harbors without fuel. Courage alone can't do the job. Fuel has become the greatest single factor in winning victory. Just a ten percent reduction in steam you use can represent hundreds of tons of coal and thousands of ton-miles of transportation to Army and Navy needs this year. Will you do your part? *Stay in there fighting!* Don't let apathy stop you. *Do something* about fuel saving!

Fuel-Saving Starts With CONTROL

An explanation of the Control exercised by Dunham Differential Steam Heating is contained in our Bulletin 614A. May we send it? Address—C. A. Dunham Co., 450 East Ohio St., Chicago 11, Ill.

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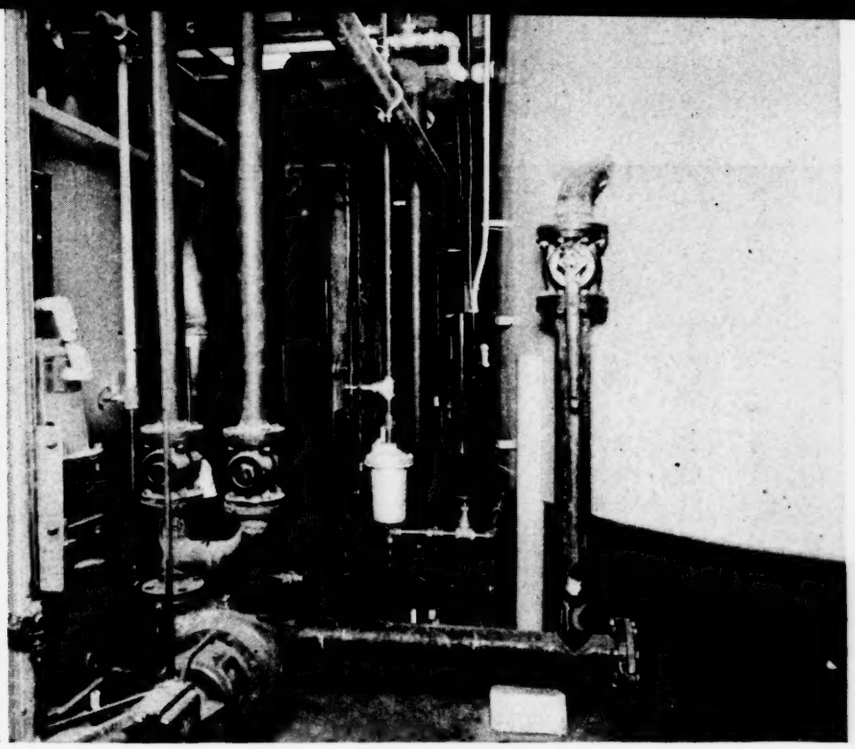
DUNHAM MAKES FUELS GO FURTHER

This Advertisement Dedicated by

DUNHAM

SYSTEMS OF STEAM HEATING

To a better understanding of the urgency of conservation in fuel use

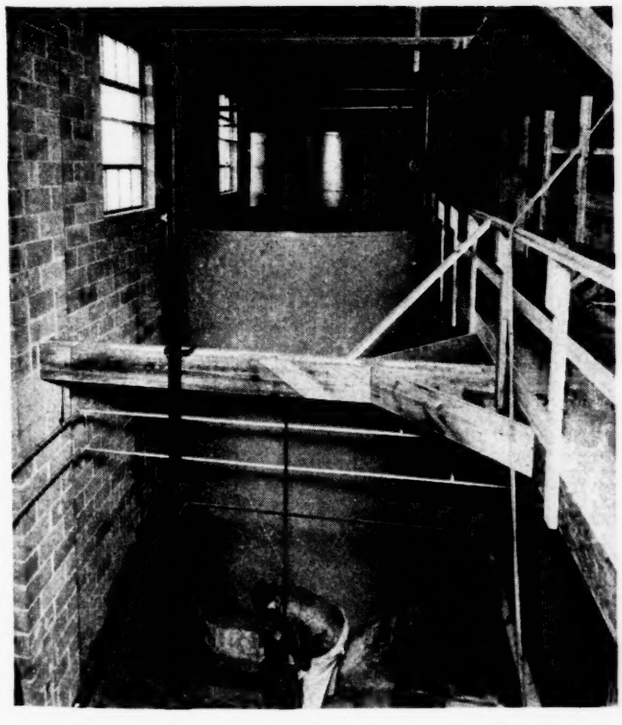


Part of the process piping required at the detinning plant. Iron plug cock valves, left, are arranged to operate from the floor, rather than from above.

Detinning Plant Uses 20,000 Feet Pipe

C. P. STOLBERG
Mechanical Engineer, The H. K. Ferguson Co.

ABOUT 300,000,000 No. 2 size cans will be handled by the new detinning plant erected for the Southern Detinning Company, Birmingham, Ala. Tin plating will be removed from the discarded cans by a process which can be divided into three general steps. Besides interest in the process itself, there were problems of design brought about by the substitution of common material for critical items.



To conserve critical material, wood was used in place of steel, wherever possible. In the foreground is the tin chalk liquor tank; in the rear, a storage tank.

When the cans arrive at the plant, it is necessary to pick out tramp iron and material with no tin content. Cans are shredded and cleaned through incineration in an oven, and by washing. All foreign matter that may be shipped to the plant with the cans is removed, and clean cans provided for the detinning process.

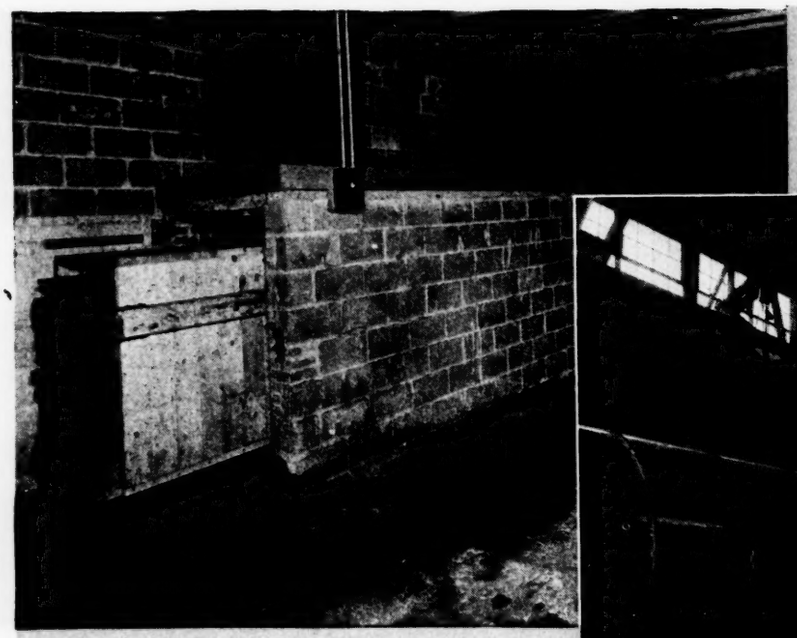
Now for the actual detinning. Clean cans are immersed in a caustic soda solution which removes the tin through chemical reaction. After the detinning step, the metal cans are washed thoroughly, and then baled as steel scrap for shipment to steel mills.

Step No. 3, the final one, is almost entirely chemical. Tin held in solution, after the detinning process, must be removed and made available as tin oxide. The chemical solution is passed through a number of tanks, and the tin oxide as a slurry is filtered out, dried, and packed for shipment.

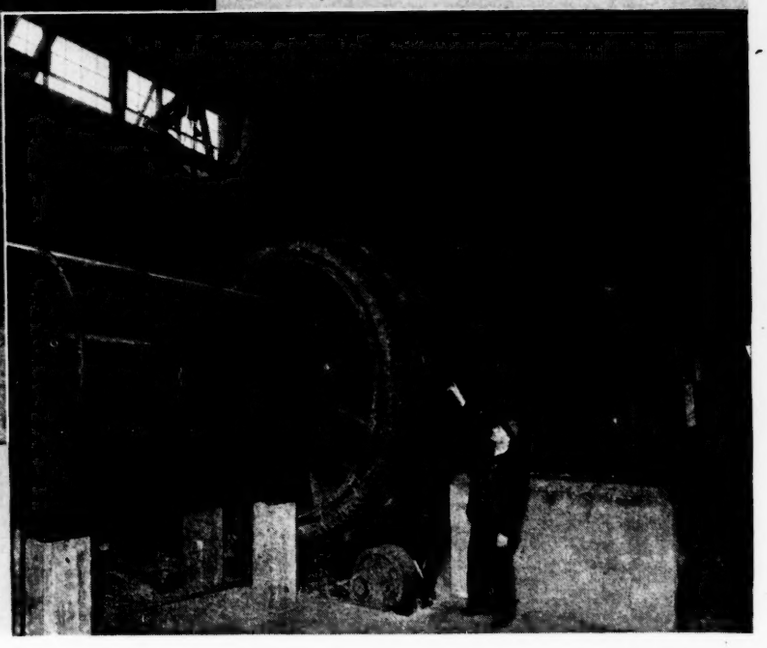
Essentially steps 1 and 2 are but the mechanical handling of the cans. The last step requires a large amount of piping to transfer the chemical solutions.

Of the 18,900 feet of pipe installed at this plant, 13,000 feet are welded pipe. The all-iron restriction on piping caused no particular difficulty because Schedule 40 standard steel pipe is being used throughout. It includes process piping, and lines for compressed air, high pressure steam, high pressure condensate, low pressure steam, low pressure condensate, gas, industrial water, and drinking water.

Welded pipe is used for all lines 2 in. and larger; threaded pipe for lines 1½ in. in diameter and smaller. Standard prefabricated welded fittings were used for elbows and flanges. However, because of wartime restrictions, about 250 lb of cast iron screwed flanges were used instead of welded flanges.



The wet chalky tin oxide is put in shallow tin pans to dry more quickly. Here is a batch of pans emerging from the warm air dryer.



Actual separation of tin from the steel body of cans takes place in this detinning drum which contains caustic soda. Sodium stannate falls to the bottom.

To heat solutions in the detinning drum tank, and the wash drum tank, 2-in. welded steel pipe coils were built on the job for use with steam. These coils were installed in concrete tanks provided with a 10-gauge steel lining, welded in place. This construction saved considerable metal over what would have been required for an all steel tank. However, it brought up the problem of the piping connections for coils and tank. Where connections were required, a ½-in. steel plate was welded to the metal lining. The pipe was brought through and welded to the plate for a watertight connection.

Valves on the process lines are 175 lb OWG all iron lubricated plug valves while those 2 in. and larger are flanged. Plug valves were selected because of the solutions employed in the process. Some solutions are heavy slurries, some saturated solutions apt to precipitate solids, and other liquids carry settled material or black mud that may contain small pieces of steel scrap and other solids. Experience has shown that the plug type valve operates satisfactorily under such severe service.

Valves are wrench operated and are oiled with a lubricant capable of withstanding caustic soda. Where throttling valves are required, diamond port plug valves were installed so that a port area of nearly square proportions can be maintained throughout the throttling action, thus aiding in the passage of heavy slurries and foreign material.

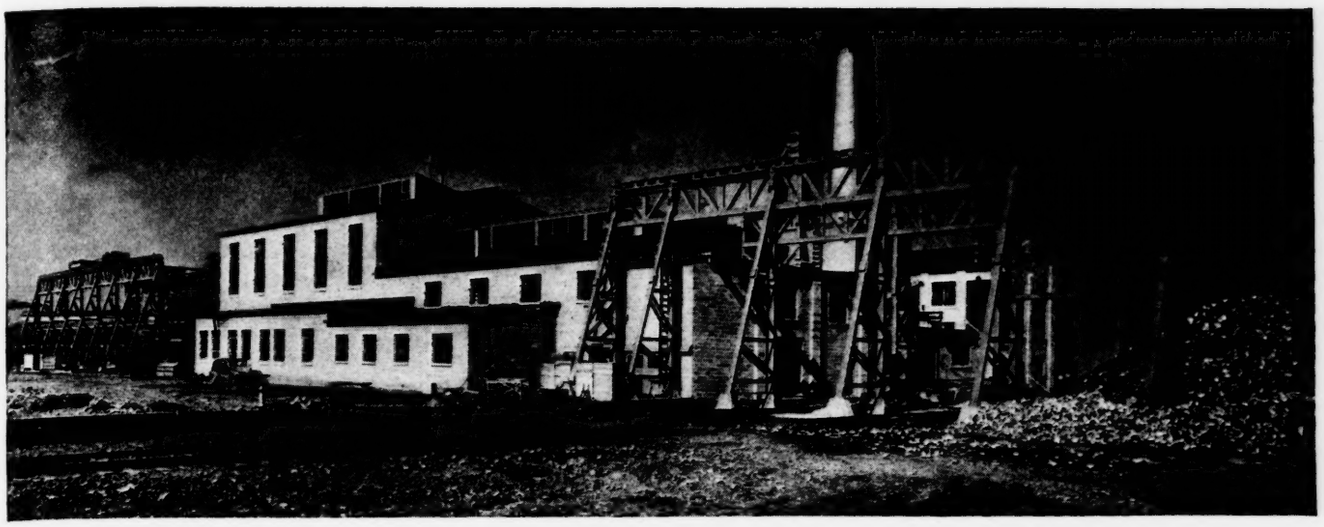
After construction, all pipe was painted with lead and oil paint, the color selected matching that of the building walls and adjoining machinery. For pipe operation identification to reveal the type material that is carried in the line, each valve is painted a specific color. This color code is in accordance with the recommendations of the American Standards Association "Recommended Practice for Pipe Identification." Valves in lines carrying valuable tin solutions are painted a deep purple to make them stand out and thus prevent costly losses through errors in operation. Other distinguishing colors were used for the drinking water, industrial water, and process pipe lines, but waste and sewer lines do not bear distinguishing colors.

Pumps Have Water Gland Seals

Twenty-four electrically operated pumps were installed to handle the various solutions throughout the process. Pumps have impellers to pass one-inch solids, and are of all-iron construction to withstand action of the chemical solutions. To reduce stuffing box leakage, pump speeds were limited to 1750 rpm. All pumps are provided with water gland seals supplied from one pump handling clean water. The pumps in intermittent service are valved to handle more than one solution or to serve in more than one process. While additional valves and piping were required, there was a reduction in the number of pumps. Not only was critical material avoided, but a considerable saving was shown.

Besides the piping within the plant, it was necessary to lay underground pipe lines for gas, water, sanitary sewers, and storm sewers. Underground gas lines, from the street main to building risers, consist of mechanical joint cast iron pipe.

Underground water lines 3 in. and larger, are made of standard bell and spigot cast iron pipe. Be-



Overhead cranes at either end of the can-preparation building expedite the handling of the cans. Unprocessed cans are in the pile at the right. In the preparation building they are shredded and cleaned and stored for later processing.

cause of the large amount of cinders in the ground at the plant site, which is conducive to accelerated corrosion of the pipe, it was necessary to provide some protection.

Steel pipe, which is used for water lines 2½ in. and smaller, was given a coat of hot asphalt, then wrapped in burlap, and given a final coat of asphalt. Each coating is about ⅛ in. thick, and the complete protection is about ⅜ in. thick.

Vitrified tile pipe is used for sanitary sewers and concrete pipe is used for storm sewers.

Birmingham has two public water supply systems, a water not completely treated which is termed the industrial water and is supplied through a separate system, and a purified palatable water for domestic needs. While the industrial water has some turbidity, it is very soft, is low in cost, and is therefore used throughout the plant for boiler water and for process work.

Also of interest at this plant is the master flow sheet showing the complete detinning process. On the flow sheets and the piping drawings, each pipe run bears an identification number. In this way, any pipe may be readily cross referenced between the piping drawings and the flow sheets. Letter symbols were used to identify material handled by respective pipe lines—*P* indicates process solutions, *A* compressed air lines, and *HS* high pressure steam. Letters are followed by a number to designate the pipe run. All branches are given separate numbers.

This identification system greatly simplified the work in the engineering department and resulted in lowered installation costs due to time saved in identifying fabricated pipe in the field.

This plant was designed and built by The H. K. Ferguson Company, industrial engineers and builders of Cleveland and New York. While it is owned by the Defense Plant Corporation, it is being operated by the Southern Detinning Company. Overall supervision of operation is provided by The Johnston & Jennings Company, Cleveland. The plant was designed and built around a process developed by the Metal & Thermit Corporation, New York City, and offered to the Defense Plant Corporation.

Direct Fired Heaters for Dehydration

Development of a direct-fired standard space heater in the form of a heater for air at 350F, desirable for dehydration and chemical processes, is a step forward in a number of respects, and particularly so at this time, considering that by their use there is an elimination of steel plate. These heaters represent a great reduction in metal from that required by steam boilers and their distribution systems.

The standard space heater has previously been used mainly for supply of air at a temperature around 140F. Much higher temperatures are required for drying vegetables, fruits, eggs, milk, meat, hemp and chemical solutions. These temperatures have been produced by using high pressure steam coils. These temperatures upon occasion have been increased still further by the burning of gas directly in the air stream; however, this can not be done where the products of combustion or the fly ash from coal are detrimental to the type material that is being dried.

Difficulties arising from contamination and securing the necessary critical materials have been overcome by utilizing the standard space heater and by recirculating the air a number of times over the heating surface. This produces a high velocity and rapid heat transfer, yet without any contamination of the air by the products of combustion.

Evaporative Cooling by Towers and Spray Ponds

T. W. REYNOLDS

Comparison of the various types of evaporative cooling methods as towers with natural draft, induced draft mechanical towers, forced draft type towers, and spray ponds.

BASICALLY, cooling towers may be classified into two groups, the mechanical draft type and the atmospheric type. In addition, the cooling function can be performed by spray ponds.

Mechanical draft cooling towers create and control air movement by power driven fans, so that performance and water temperatures are under positive control at all times. This is particularly desirable for wartime process work. Although fans and motors are critical items, the total motor horsepower required for fans and pumps is not much greater than that required for the atmospheric or natural draft type. This is due to the greater pumping head required by the atmospheric type.

In the comparative tabulations given in Table 1, note that for identical performance, the atmospheric deck tower requires an excess in ground space and pumping head. Due to excessive drift losses there is an increase in make up water and water treatment. Besides, large quantities of critical materials, such as steel, cast iron and lumber are required. Transportation costs for these items are much higher. The tower is far from pleasing in appearance, requires more man hours to erect, and costs more for installation, operation and maintenance. The tower is heavy, unattractive, and cumbersome and is too expensive for the degree of cooling obtained.

TABLE 1.—COMPARATIVE CRITICAL MATERIALS AND TRANSPORTATION REQUIRED FOR IDENTICAL CAPACITIES AND TEMPERATURE CONDITIONS. ATMOSPHERIC DECK TOWER VERSUS INDUCED DRAFT TOWER.

	Atmospheric Deck Tower	Induced Draft Tower
Capacity—gpm	13,100	13,100
Wind—mph	0	0
Design performance—Deg. (hot, cold, wet bulb)	100-80-70	100-80-70
Size—ft—W x L x H.	12 x 710 x 45	60 x 90 x 24
Basin area required—sq ft	10,000	5,700
Pumping head at base—ft	45	26
Lumber—bd ft	290,000	125,000
Structural steel—lbs	—	3,650
Bolts and nails (galv. steel)—lbs	10,500	7,000
Reinf. steel for basin—lbs	24,100	10,600
Cast steel, parts—lbs.	—	2,400
Motors—lbs	2,600	3,600
Cast iron—lbs	150,000	20,000
Weight of all metal parts—lbs	187,200	47,250
Weight of all materials except concrete—lbs.	1,115,200	447,250
Concrete for basin—cu yds	450	210
Freight in carloads	23	9
BHP for pumping	175	100
BHP for fans	0	132
Connected motor, hp.	175	250
Drift losses—per cent.	1 to 2	0.1 to 0.2
Make-up water—gph.	8,000 to 16,000	800 to 1,600

Note: Weight of lumber taken dry at 3.2 lbs per board foot. A spray pond due to lower thermal efficiency would require 16,400 gpm and a basin area of 40,000 sq ft.

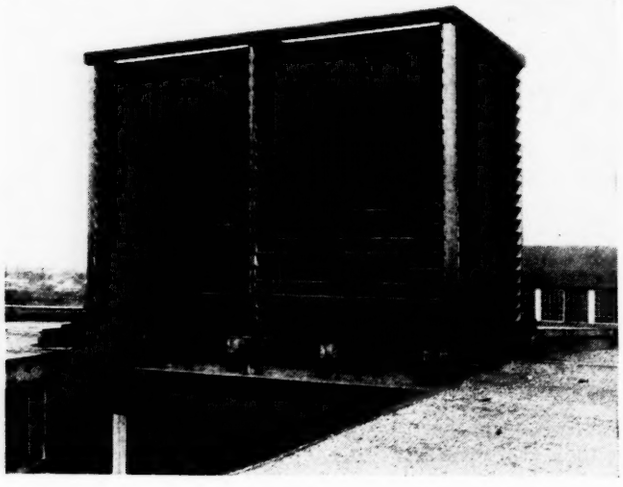


Fig. 1.
Natural draft evaporative cooling tower. Photo courtesy Spraying Systems Co.

An atmospheric deck type cooling tower that is designed for a higher wind velocity than it will generally receive, cannot be considered dependable equipment for uninterrupted production. The desired cold water temperatures cannot be maintained with less wind, or during calms, or when the wind is blowing lengthwise or obliquely to the long axis of the tower. Therefore, since winds are not reliable as to direction, velocity or continuity, towers must be designed for zero miles per hour wind velocity. Otherwise, they are not comparable to a mechanical draft tower.

Atmospheric or Natural Draft Tower

In the atmospheric, wind, or natural draft deck type tower, the warm water is distributed over the top of the tower and drips from deck to deck to the

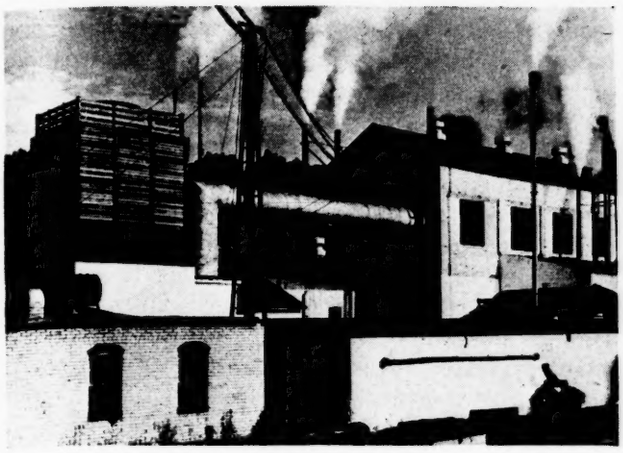


Fig. 2.
Induced draft tower of the conventional type serving a blast furnace air conditioning system. Dry air of uniform temperature is supplied to the furnaces.

basin below. It presents a maximum of wetted surfaces to the air. The performance of such a tower is not only dependent on the whim of the wind, but since the tower is narrow in relation to length and height, it must be well anchored to resist overturning by high winds. This is more common in the south and the west, or where summer breezes prevail in one general direction.

In modern towers, the drift nuisance and make up water are less when secondary louvers are applied to the tower exterior to prevent stratification of air at high velocity in a few shallow planes. Efficiency was increased by the more recent use of double battened decks. In turn, the decks decrease the size, weight, height and pumping requirements of the tower.

An atmospheric tower may be of the spray type. Such models are not as dependent upon wind or wind direction, for the falling spray water induces air through the louvered sides of the tower, in the absence of wind. The capacity varies from 0.6 to 1.5 gpm water per square foot of tower area. Wetted area of louvers add to the surface of water exposed to the air. Drift losses are lowered due to well louvered sides and lower height. Generally, the first cost is less as is also the maintenance, and pumping head required.

Mechanical Draft Tower

The mechanical draft tower, frequently used with air conditioning installations, is usually located in populated places. It must overcome certain limitations such as appearance, weight to be supported, space required, and objectionable noise or drift. These can be overcome in various ways. Double cased towers prevent water leakage and staining of exterior casing. Drift losses are only 10% of those with the natural draft type. Generally, fans are of small power, and have metal-saving airplane propeller type wheels. Non-corrosive plastic blades of adjustable pitch give a low noise level for tip speeds from 9,000 to 10,000 fpm. Flared or venturi shaped ring inlets are used to decrease power requirements and noise.

The tower is often built as a part of the building structure, or concealed from street view. It may be painted to improve its appearance though this is not necessary merely to preserve the redwood.

Much of the redwood is interlocked by means of mortises and tenons, thus avoiding nails and bolts. Cast iron substituted for the more critical steel parts formerly used gives lower cost, less corrosion, longer life, neater parts and saves in manpower and time of erection. Wheel diameters of fans up to 15 or 16 ft are now common, and this is an advantage, as the larger the fans, the less wiring and starters are required. Motors, when located in the air stream, are fully enclosed; when located outside of the fan ring and air stream, they are splashproof. One design employs a right angle gear box with fan wheel on the low speed shaft, and with the high speed drive shaft long enough to locate the motor outside of the fan ring and air stream. Two-speed motors are used in year-around operation. They give greater flexibility and require less power.

The mechanical draft tower can obtain a close approach to the wet bulb with a long cooling range. About 3 gpm of water is circulated per ton of refrigeration in air conditioning installations with a distribution per square foot of tower of from 2 to 6 gpm. Pumping heads vary from 20 to 26 ft; draft losses are from 0.35 to 0.45 in. of water; and velocities through the decking or fill area are from 325

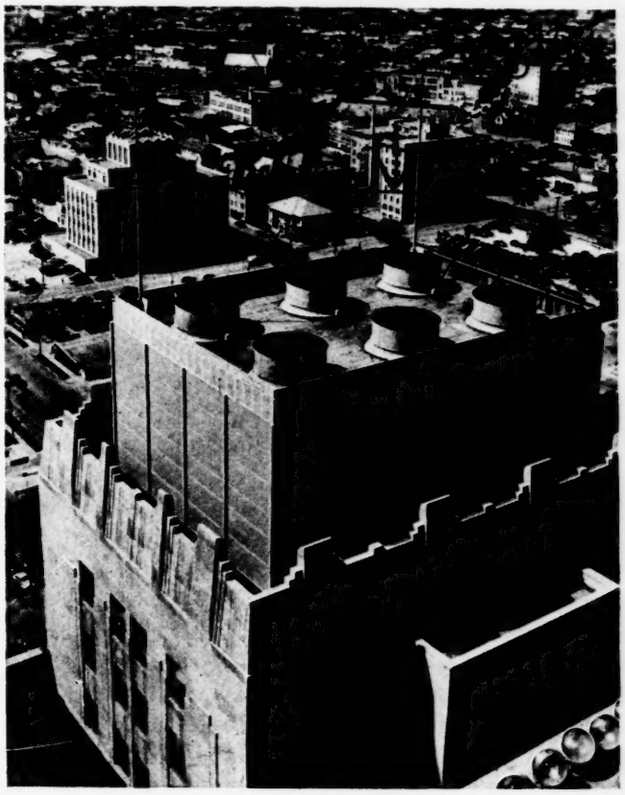


Fig. 3.
Induced draft towers can harmonize with the building parapet which surrounds it. Photograph shows a 6-fan tower. Photos courtesy The Marley Co., Inc.

to 350 fpm. Although the mechanical draft tower uses smaller amounts of air for the same work, nevertheless the air must be moved by fans with a power that increases approximately as the cube of the air quantity.

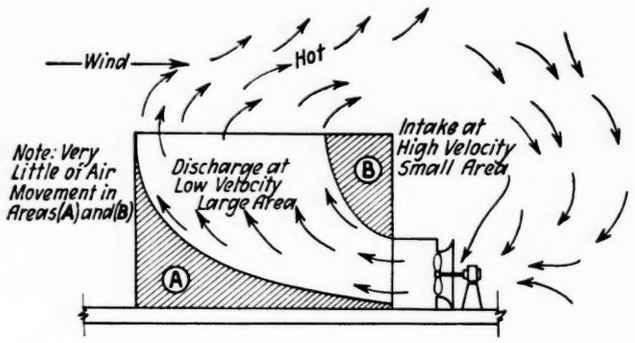


Fig. 4.
Tendency of a forced draft fan to recirculate a percentage of the discharge air, and to by-pass certain cooling areas.

The time the air is in contact with the water and the surface area of the water in contact with the air can be increased either by increasing the height of the tower, in which case the pumping power is substantially increased but the fan power only slightly so, or by increasing the area of the tower, without any change in fan power, in which case the velocity of the air is decreased. Although the air quantity is slightly increased in the latter case, so as to decrease the time the air is in contact with the water, the increased air quantity results in an increase in the average differential between the temperature of the water and the wet bulb. As a consequence, the rate of heat transfer is increased.

Comparison of the Two Types

A mechanical draft tower may be of the induced draft type or the forced draft type. The induced draft tower is trim in contrast to the forced draft tower where fans, drives, fan housings and guards stand out from sides near the base. In the induced draft type, all mechanical apparatus is in a readily accessible protected location on top of the structure.

Fans in the forced draft tower discharge horizontally into the cooling area so that hot saturated air leaves at the top at low velocity over a broad area. As a consequence, air tends to be driven by the wind to the partial vacuum set up by the wind at the lee side of the structure, and by the high velocity air intake along the base. (See Fig. 4.) Some tests have proven that suction areas may extend as far as 150 feet from the lee side of the forced draft structure, especially so in the case of large multiple installations. The tower must be 12 to 15% larger to make up for the reduced capacity caused by recirculation of the hot saturated discharged air. Costly stack extensions would, of course, alleviate this condition.

No such difficulties are encountered with the induced draft tower for the used air is discharged from fans at the top of the tower. Discharged air moves upward at high velocity over a concentrated area, and the outdoor air is drawn in along the base from all directions over a broad area and at low velocity. (See Fig. 5.)

Maximum efficiency with moderate fan power is obtained with the induced draft type due to more uniform air flow throughout its entire cooling area. In the forced draft type, there tends to be larger areas in which there is very little air movement. This is illustrated in Fig. 4. The air blast from relatively small fans is shown turning at right angles against the resistance of the fill. The directional change also requires additional fan power.

The vertical discharge from the induced draft fan has still other advantages. Noise travels upward along with the discharged air. The high speed of the fan wheel prevents water from accumulating on the fan, which, coupled with the heated air, keeps the fan free from ice. Water falling in forced draft towers keeps the fans wet. This promotes corrosion, and icing in the colder inlet air. In severe weather in the colder climates, the fans must be stopped and production interrupted while the tower carries on as best it can as a natural draft tower. For such cases, towers sometimes were extended upward with stacks to increase the natural draft during the times the fans did not function.

Spray Coil Cooling Towers

The induced draft tower, when used with an atmospheric heat exchanger, has proven to be efficient and a flexible means of meeting the growing demand for specialized cooling apparatus. Cooling is accom-

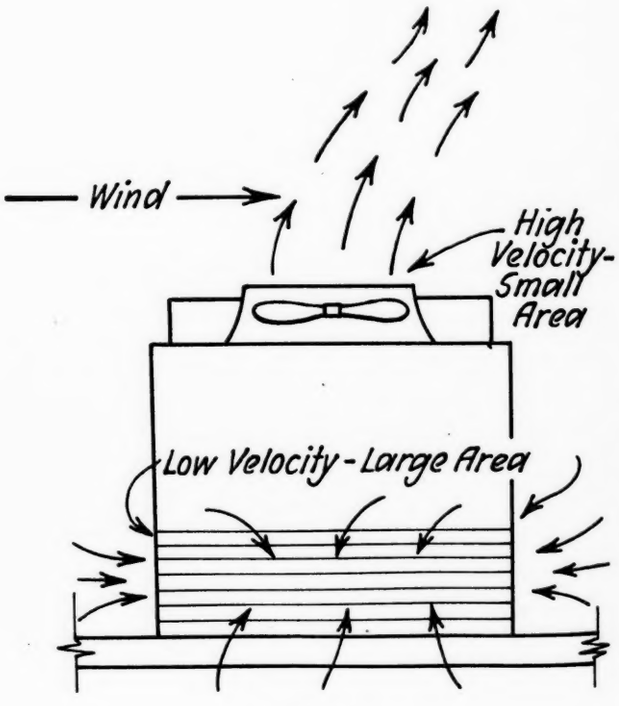


Fig. 5.
Negligible effect of wind on positive discharge of induced draft fan.

plished by spraying the water in a cooling tower over the heat exchanger tubes. Inside of these tubes are circulated fluids and gases to be cooled, such as quenching oil as used in heat treating processes, gas and distillates, or engine jacket water. · Coils containing different fluids or gases may be installed in a single tower, and the heat transfer may be at high or low pressure from water to water, gas to water, oil to water, or any other combination.

Advantages and Disadvantages of Spray Ponds

Upon occasion, evaporative cooling requirements can still be met by spray ponds, particularly where land is cheap, for large areas are required to obtain the same efficiency as with other means of evaporative cooling. The combined weight of the spray system and the water makes spray ponds too costly for roof locations. Therefore, they are built on the ground and confined by a concrete basin with a louvered fence to lessen drift loss and nuisance. The basin cost can be eliminated where it is possible to locate the spray system on wooden piers over an adjacent lake, dammed-up stream, or natural earth basin. Sometimes the spray is eliminated entirely, and a natural pond used for evaporation from the water surface. In this case, the suction intake is taken from the bottom of the pond where the cooler water settles, and at a point as far as possible from the discharge connection.

Spray ponds have certain advantages such as elimination of fans, lower pumping heads due to ground location, and slow depreciation due to the use of cast iron pipe, fittings, and bronze spray nozzles. On the other hand, the wind often carries the spray for blocks, rusting all equipment in the neighborhood. Frequent painting is required; surrounding areas become muddy and roads slippery.

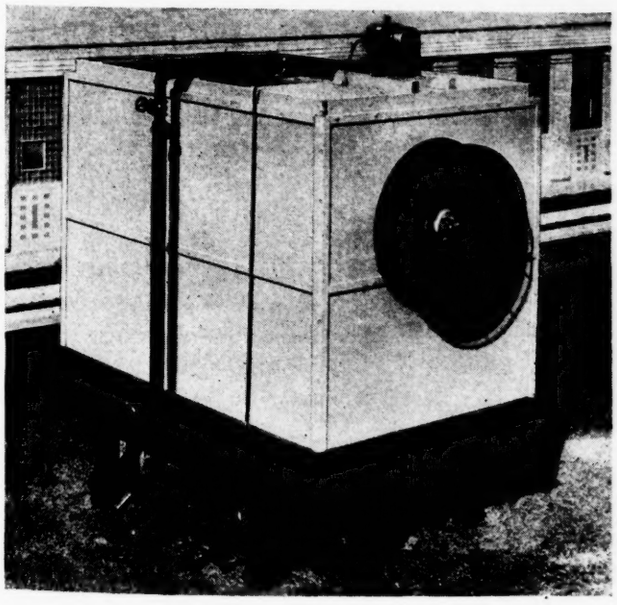


Fig. 6.
Single flow horizontal air flow tower. Photos courtesy The Marley Co., Inc.

Fig. 7.
Modern type spray pond installation. Both the concrete basin and the spray system have been sectionalized. One of the three sections is shown in operation.

It is not feasible to build a spray pond for extreme cooling conditions, as where a close approach to the wet bulb is required with a relatively long cooling range. Generally, with spray ponds, the approach and cooling range are equal. In other words, if the pond has a cooling range of 15F, the cooled water will approach downward to within 15F of the prevailing wet bulb. Better performance is possible

Fig. 8.
Small one-section pond surrounded by a louver fence. This is located on an ice plant roof.

by spraying twice, but this doubles the costs for concrete basin, louver fences, piping, and nozzles. A spray pond has a low thermal efficiency and requires from 5 to 6 gpm of water circulated per ton of refrigeration.

Factors which affect the performance of a spray pond are velocity, restriction of the wind by trees or buildings, wind direction to the long axis of the pond, size and shape of pond, the wet bulb temperature, and cooling range. Suitable nozzles must be used with adequate water pressure, spacing, and elevation above the basin. Droplets discharged from the nozzle must be as fine as possible without the possibility of the droplets drifting away.

Performance may be improved by placing the long axis of the pond at right angles to the breeze, increasing nozzle height above basin sides, increasing height and fineness of spray so as to increase the quantity of air contact with water, decreasing pond width while increasing its length, decreasing the amount of water sprayed per unit of pond area, and

TABLE 2.—RECOMMENDED ENGINEERING DESIGN AND DATA FOR SPRAY PONDS.

Nozzle capacity—gpm	30 to 50
Number of nozzles per 12 ft	
Length of pipe (or per group head)	5 to 6
Height of nozzles above basin sides—ft	7 to 8
Pressure at nozzles—lbs per sq in	5 to 7
Distance from pond side—no fence—ft	25 to 35
Distance from pond side—fenced—ft	12 to 18
Distance between spray lateral piping—ft	25
Height of louver fence—ft	12
Depth of pond basin—ft	4 to 5
Friction loss allowed per 100 ft pipe—ft	1 to 3
Design wind velocity—mph	5

avoiding any sudden sharp reductions or restrictions in pipe, fittings and nozzles. Table 2 gives recommendations as to engineering data and design for spray ponds.

Louver fences for spray ponds are built with concrete, redwood, and cypress. Cast iron posts are used with graduated louver spacing from wide set at top to provide suitable air passage and increased cooling, to narrow set at the bottom to stop drift at the level where it is most concentrated. The louvers are horizontal and overlap so that the air in changing direction while passing through the louvers, leaves behind the heavier water drops. Louvers may be necessary only on the lee side. If the outer nozzles are at a sufficient distance from the edge of the basin, louvers may be omitted.

Building codes and insurance regulations often require that cooling towers be fireproof. But steel is not available today, and if used will increase the cost fully fifty percent. Towers of California redwood are the usual thing because of lightness, workability, long life and availability. Gulf or swamp cypress is also used, although in limited quantities, because it is not so available.

Freezing of cooling apparatus in spray ponds and spray towers may be prevented by reducing the nozzle pressure so as to increase the size of water droplets; in the atmospheric deck tower by operating a second distribution system halfway down the tower to give a shorter contact of the water and air; in the mechanical draft tower by reduction of fan speed; and in any system discontinued from service, by drawing off all water from the basin.

Army Cooking and Heating Units

"Camouflage discipline" is constantly practiced by Army troops in or near the front lines. One of the surest indications of an otherwise well camouflaged position is the appearance of a light or flame at night. In the daytime, smoke from fires is like a sign post advertising the whereabouts of troops.

Even soldiers in combat must have hot food occasionally, and fires to warm themselves. The problem has been to furnish them with cooking and heating units that could be hidden from enemy eyes and burn with invisible, smokeless flame. In active theaters of operation, soldiers' food is cooked over a gasoline range known as the M-1936. Mounted three abreast in trucks, these ranges are moved up to the front lines from protected areas under cover of darkness. Hot food is served directly into the men's mess kits. Breakfast is prepared and served before daylight. Then the kitchen trucks move to the rear for another load of hot food. Lunch, the only cold meal of the day under this plan, consists of sandwiches or a combat ration. Although tactical consideration may alter this schedule, American fighting men in this war have greater opportunities to eat hot food than the members of any army in history, thanks to the mobility of the M-1936 ranges.

Utilization of this model gasoline range has not been without its problems. Although the M-1936 worked perfectly on the white unleaded gasoline available in this country, the heavily leaded aviation and motor gasolines found in combat zones clogged the fuel filters. It was necessary to develop new type filters and tests have shown these to be many times more efficient than the ones they replaced.

Another problem was overcome when a vacuum system was developed to prevent the gasoline from flooding the burner mixing chamber at low temperatures. The blue gasoline flames are not visible to enemy eyes but the flooding of the chamber often resulted in dangerous and easily seen fires. Special down-draft burners using fuel oil, kerosene or gasoline have recently been developed and these will become available in quantity to our fighting men within the next few months. Tests have shown them to be practical in use and free from smoke. Continued experiments are being carried on to improve ease and operation of control, ease of maintenance, fuel economy and durability.

Other types of heaters and ranges developed by the Quartermaster Corps for use by our troops include a midget model, weighing less than 1½ lb, made especially for soldiers alone or in small groups. Then there is a new immersion type water heater which is placed directly in the can of clear water used for rinsing mess kits. It heats the water more quickly than models placed under the can and consumes less fuel. It operates on gasoline, fuel oil or kerosene and gives off no visible flame. It is contained inside its own can for moving and saves 50% in weight and space.

Insofar as heating tents or temporary quarters is concerned, the Quartermaster Corps has developed an adapter unit which is used in conjunction with the regular Army tent stove. It permits the burning of gasoline, fuel oil or crankcase drainings, and tests have disclosed that it provides heat comparable with that from the maximum amount of coal the stove will hold.

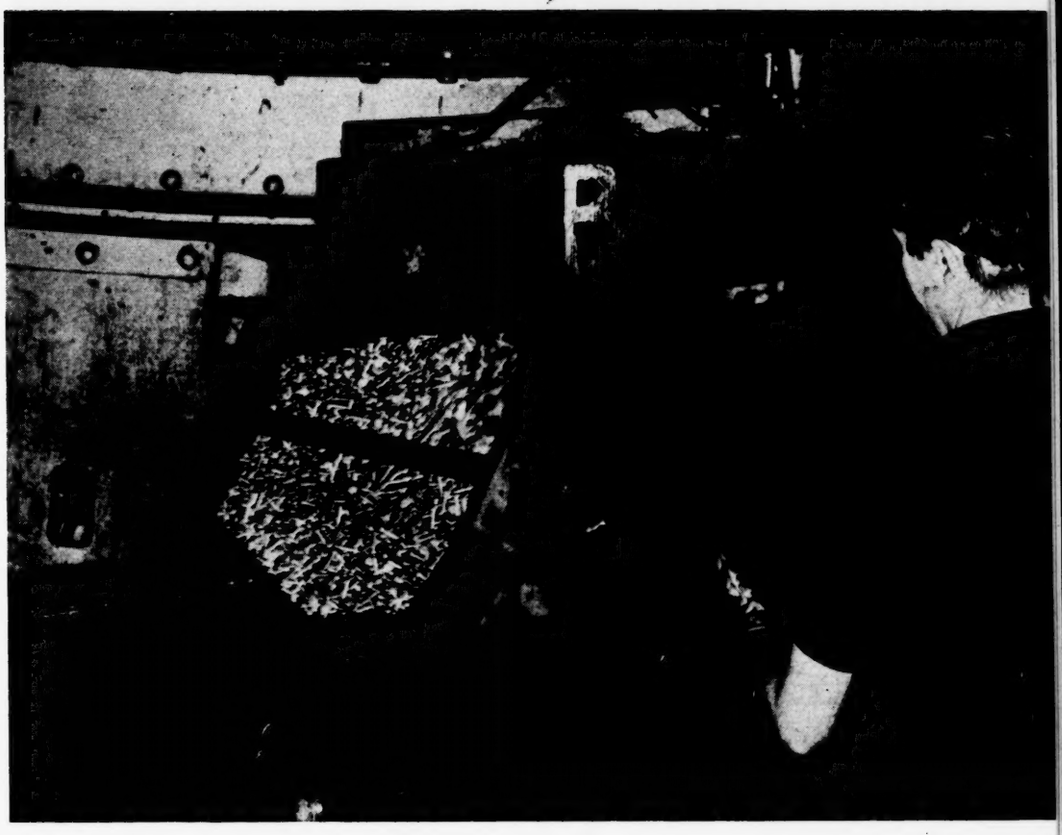


Fig. 1. After the aluminum alloy rivets are heat treated, they are rapidly quenched in cold water. Refrigeration prolongs the benefits to the alloys obtained by this heat treatment.

Refrigeration Retards Age Hardening of Aluminum Alloys

F. KELLER

Chief, Metallography Division, Aluminum Research Laboratories, New Kensington, Pa.

REFRIGERATION, for preventing the age hardening of heat-treatable aluminum alloys used for rivets and various aircraft parts, has aided greatly in speeding up production in aircraft plants. It has been responsible for the elimination of many inconvenient and uneconomical fabricating practices. Refrigeration does not alter the characteristics of the various aluminum alloys in any way; it simply retards the natural age hardening process and keeps the material in a soft and workable condition.

Some aluminum alloys, particularly those used for rivets and other aircraft parts, undergo significant changes in strength and workability on aging at ordinary temperatures for several days, after the parts were heat treated. The increase in strength that occurs is desirable and important but it is accompanied by a corresponding decrease in workability.

To avoid difficulties in heading rivets or in forming parts from aluminum alloys of this type after heat treatment, two procedures are available. One involves carrying out riveting or forming operations as soon as possible after quenching and before appreciable age hardening takes place; the other consists in utilizing some type of refrigeration to chill and to maintain the material at a sufficiently low temperature to prevent age hardening from taking place up to the time when the heading of rivets or the forming of parts can be done conveniently.

Aluminum alloys, shortly after they have been heat treated, start to age or harden at room temperature. Riveting or bending becomes difficult. By storing the parts at cold temperatures, after the metal has been heat treated, the natural aging is retarded. The alloys remain workable over a longer period. Refrigeration has eliminated costly repetitions of heat treatment, and has speeded production in airplane plants.

Prior to the use of refrigeration for retarding

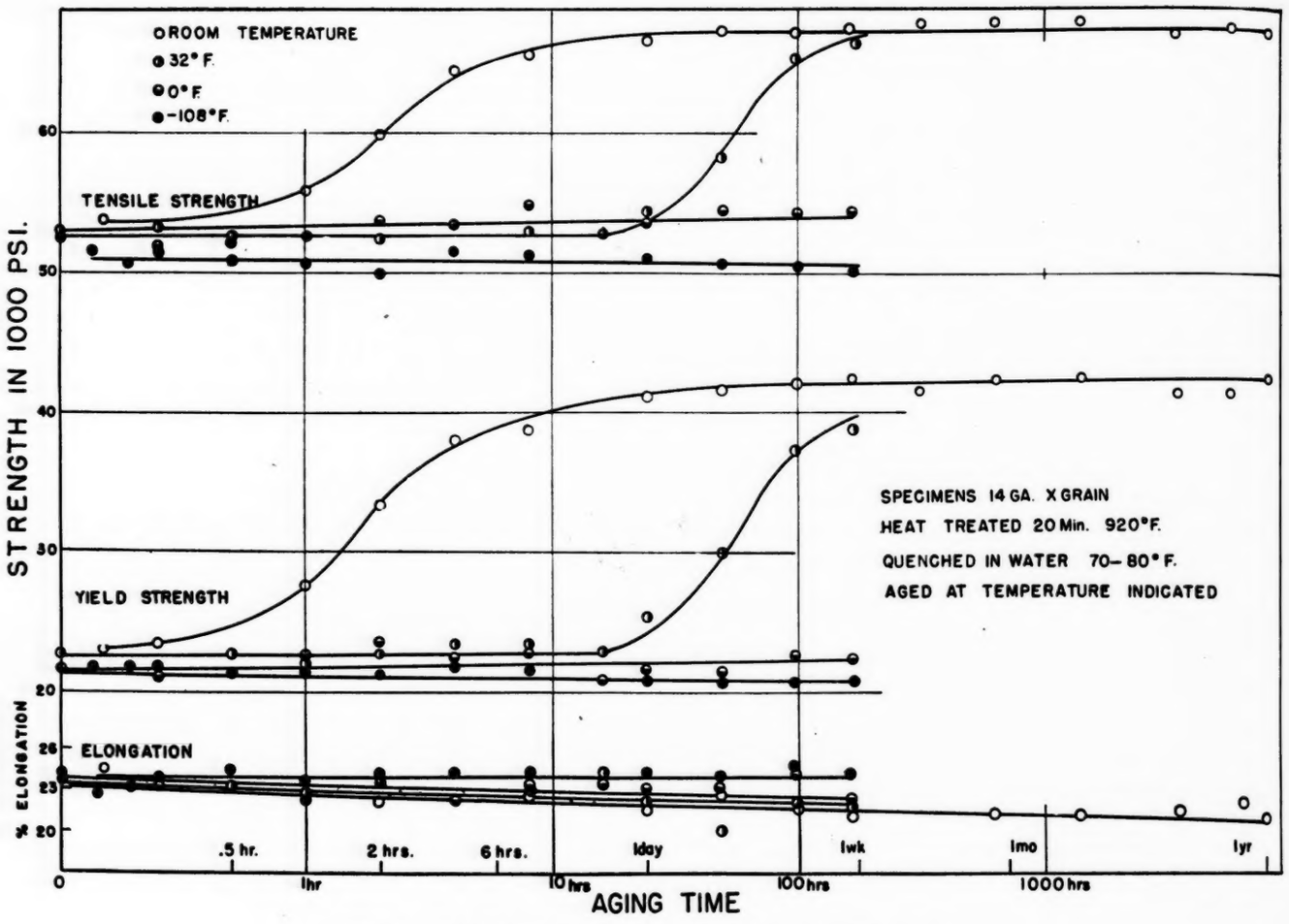


Fig. 2. Natural aging of 17S at various temperatures.

the age hardening of aluminum alloys, it was general practice to heat treat aluminum alloy rivets or parts and then to head or form them within a period of one hour or less after quenching. Any rivets or parts that were not driven or formed within this period soon became too hard for working and had to be heat treated again. This was an uneconomical and inconvenient practice. It has been eliminated largely through the use of refrigeration.

The sole purpose of refrigeration is to prevent natural age hardening of the heat-treatable aluminum alloys and is not designed to shrink the rivets so they will fit the rivet holes better, as has been sometimes stated. Moreover, rivets are not more workable at low temperatures than at ordinary temperatures. Chilling, therefore, is not used to obtain improved workability but to retain the workability of the material in the "as-quenched" condition.

Heat-Treatable Aluminum Alloys

The desirable high strength and hardness of heat-treatable aluminum alloys are the result of two distinct structural changes: (1) the formation of a saturated solid solution by heat treating the material in a temperature range where the alloying constituents are appreciably soluble, and the alloying material is retained in solid solution by rapid quenching; (2) the subsequent precipitation of particles of constituent from the solution which grow to a critical size during aging at room temperature, and which greatly increase the strength and hardness.

For rivets, the heat-treatable alloys A17S, 17S and 24S are in general use. For sheet and other products, the latter two alloys are more or less standard. All of these alloys undergo an appreciable amount of age hardening upon standing after heat treatment and will develop their maximum strength and hardness on aging at ordinary room temperature for about four days. A comparison of the mechanical properties of A17S, 17S and 24S in the annealed, "as-quenched" and the fully aged conditions is given in Table 1.

Immediately after quenching, these alloys are relatively soft and workable. Therefore, working operations such as riveting, bending and drawing can be performed without any tendency for cracking the metal. The alloys, however, start to age harden immediately and their ability to withstand deformation decreases. Rivets of A17S alloy will harden only to an intermediate strength and fully heat treated and aged rivets of this alloy can be headed readily without any tendency for cracking to develop. Rivets of this alloy seldom require the use of refrigeration unless extremely severe forming operations are required as, for example, when large rivets are driven with fully formed heads. Alloys 17S and

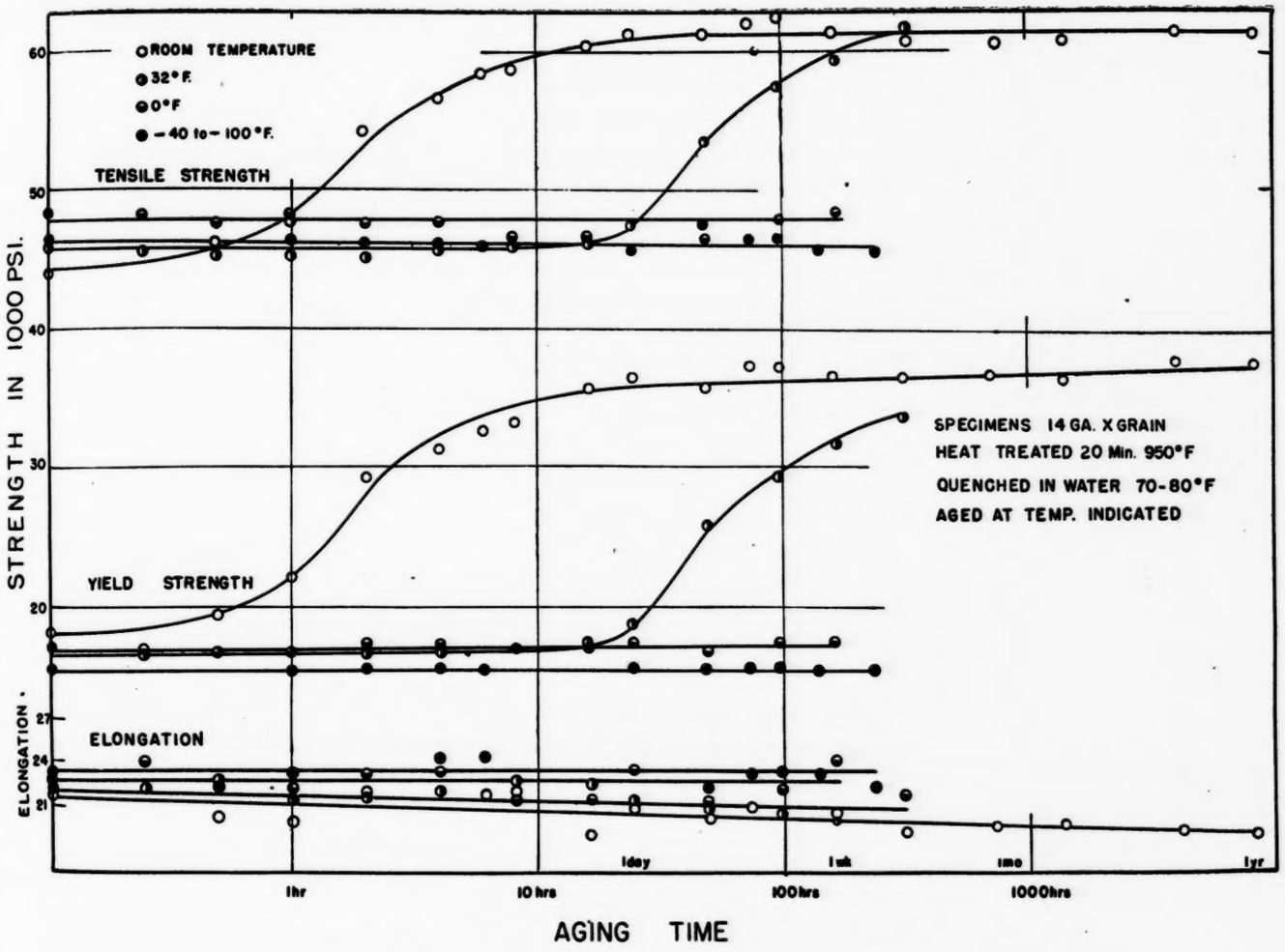


Fig. 3. Natural aging of 24S at various temperatures.

24S, however, age harden rapidly after heat treatment. These alloys should be worked within a short time after quenching or the material should be stored at a low temperature immediately after quenching to maintain workability. There is, however, an increasing tendency to drive the smaller sizes of 17S rivets in the fully aged condition to avoid the necessity of refrigeration and also to take advantage of the resulting higher shear strength.

TABLE 1.—MECHANICAL PROPERTIES OF ALUMINUM ALLOYS IN VARIOUS TEMPERS

Alloy	Condition	Tensile Strength, Lb. per Sq. In.	Yield Strength†, Lb. per Sq. In.	Elongation, % in 2 In.
A17S-O	Annealed (O)	20000	8000	24.0
A17S	"As-quenched"*	21000	10000	28.0
A17S-T	Heat treated and aged 4 days (T)	43000	24000	24.0
17S-O	Annealed (O)	26000	10000	20.0
17S	"As-quenched"*	47000	17500	25.0
17S-T‡	Heat treated and aged 4 days (T)	62000	40000	20.0
24S-O	Annealed (O)	26000	10000	20.0
24S	"As-quenched"*	52000	22000	20.0
24S-T‡	Heat treated and aged 4 days (T)	68000	45000	19.0

*Tests of material in "as-quenched" condition were completed within 5 minutes after quenching.
†0.2 per cent set.
‡Typical properties.

Retarding Age Hardening

The natural age hardening of these heat-treatable aluminum alloys can be retarded effectively by chilling the material rapidly after heat treatment, and maintaining it at a low temperature.[1] Thus, rivets and other products in these alloys can be kept in a soft and workable condition until heading or other forming operations can be carried out conveniently. The material must be held continuously at a low temperature to prevent age hardening since it will start to harden if room temperature is approached. Subsequent chilling will retard any further hardening but it will not restore the original workability.

Refrigeration of aluminum alloys provides a convenient and economical means of maintaining the heat treated alloys in a very workable condition up to the time the working operations are carried out. When the materials are again allowed to reach nor-

[1]E. H. Dix, Jr., and F. Keller, "Experiments on Retarding the Age Hardening of Duralumin," Inst. of Met. Div., A.I.M.E., Transactions 93, 440-47 (1931).

mal temperatures, natural aging will progress to completion in the usual manner. The advantages of this method of maintaining workability are obvious and are especially adaptable in large aircraft plants where riveting and forming operations are carried out at many places. Large batches of rivets or other parts may be heat treated, and when chilled and stored under the proper temperature condition, may be distributed to the various locations where they are to be used. For this distribution, suitable portable storage units refrigerated mechanically or by dry ice have been used to advantage. Dry ice is employed extensively because it provides low temperature rapidly and because it is adaptable for use in relatively simple and inexpensive containers.

Temperatures for Retarding Age Hardening

The age hardening characteristics of 17S and 24S alloys at various temperatures are shown by Figs. 2 and 3. For both of these alloys, age hardening is practically complete after four days storage at room temperature. As the storage temperature is lowered, age hardening is retarded. Thus, for example, at a temperature of 32F, substantially little hardening occurs in a period of 16 hours after which hardening starts and progresses slowly over a period of two weeks. When a storage temperature of 0F is employed, age hardening is completely retarded for a period of one week or more. At still lower temperatures, hardening would be entirely retarded over a much longer period.

In employing refrigeration practices for retarding hardening, it is important that the rivets or other parts be quenched rapidly and chilled as quickly as possible to the low temperature employed for storage. Thus, it is advantageous to use refrigerated quenching baths and rapid chilling units. For all practical purposes, a storage temperature of 0F is satisfactory for 17S and 24S alloys although some plants use temperatures of —30F and lower. Although the lower temperatures provide a wider margin of safety, the rivets are more difficult to handle when very cold because they tend to stick to the workman's fingers and tend to form frost from moisture in the atmosphere. In some instances, the rivets after quenching are given an alcohol rinse to remove residual water and prevent the rivets from sticking together when they are chilled. They may be stored in kerosene, alcohol or mixtures of these liquids to obtain rapid chilling and uniform maintenance of temperature.

New Bidding Practice for Building Materials

With the hope that competitive bidding practices in the construction of homes, factories and other building projects may be improved and dissatisfaction prevented on the part of ultimate building owners, a new "Bidding Practice for Building Materials" has been proposed by the Producers' Council. This plan has been approved in principle by the American Institute of Architects.

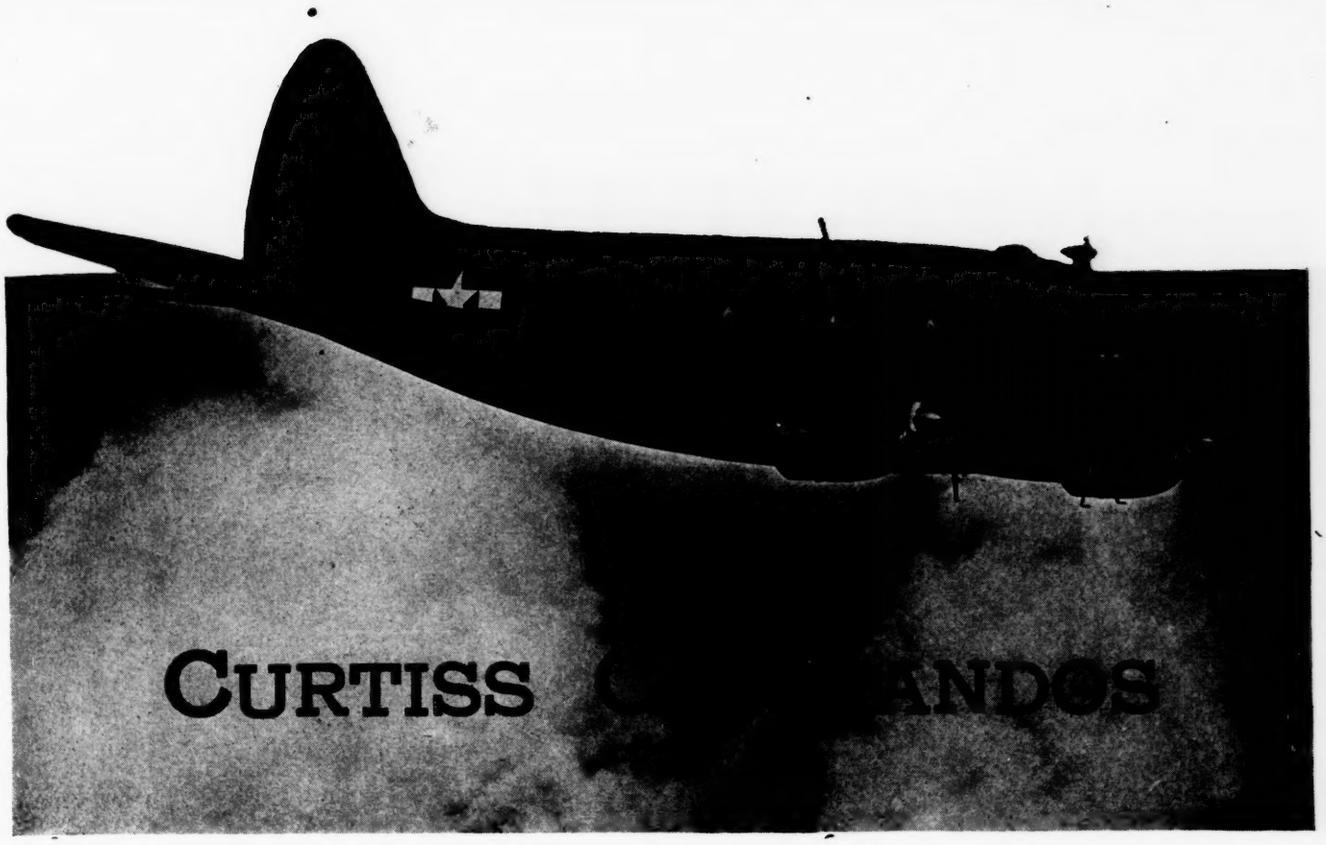
It has been stated that the use of the "or equal clause" has permitted contractors and sub-contractors to figure their bids either on the makes of building products named in the specifications or on other products which they consider acceptable as offering equal quality and value. This difference of opinion in many cases has caused confusion and sometimes has resulted in the use of a product of lower quality. Under the new procedure the specifications will state that the basic bid shall be figured on the makes of building material and equipment named in the specifications, but will permit the contractor or other bidder to propose the use of alternative products at the same prices or at a higher or lower price for which he quotes an exact addition to or deduction from his basic bid for each alternative. This new bidding practice will give the contractor or sub-contractor a wide latitude in proposing the use of particular makes of building products. The architect and owner then will know exactly what brands or types of materials or equipment may be expected from each bidder, and at what prices. Bids may then be compared and evaluated on a more acceptable basis.

This proposed plan will also protect contractors and suppliers from finding themselves obligated to deliver any other building products than those on which they have bid.

At the last annual meeting of the American Institute of Architects a resolution was adopted which stated:

"Competitive bids must, as far as practicable, be based on identical materials and methods as well as quantities in order to permit valid price comparisons. Whenever more than one material is specified or permitted for a particular use, it is desirable that the specifications should state clearly which material is to be used as the basis for the estimate. Alternate estimates should be separately submitted, for the substitution of any alternative equivalent materials that may be mentioned or permitted in the specifications, in the form of additions or deductions to be applied to the estimate if such alternative materials are adopted."

According to F. J. Plimpton, chairman of the Council's Technical Cooperation Committee, the plan is recommended for general adoption by architects, engineers, contractors, sub-contractors, material concerns, and others involved in bidding on construction projects.



These cargo carrying planes are spray painted in rooms provided with heated double filtered air that is later exhausted through a water curtain.

H. W. TOMPKINS
Curtiss-Wright Corporation, Buffalo, N. Y.

HEATING and ventilating have an important part in the production of Curtiss (C-46) Commandos, particularly in the operation of the giant spray room where the 76-foot fuselage is painted.

The Commando, giant cargo carrier and largest twin-engine transport in production, is serving in many parts of the world carrying vital material from medical supplies to jeeps and artillery, urgently needed in the far-flung bases of operation.

In answer to the insistent Army demands, the Curtiss-Wright Corporation has been stepping up the output of these planes, but as the production increased, the problem of painting the massive fuselages became one of major importance.

Although camouflage-painting by contractors is gradually being discontinued, the unusual features of the heating and ventilating installation in the spray room at the Buffalo plants of the corporation are of interest to engineers.

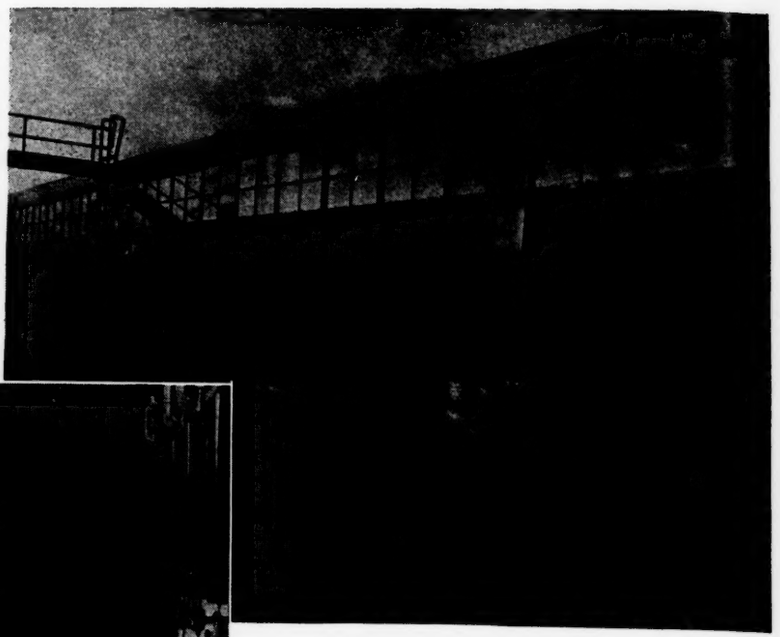
The fuselage of this sky giant measures 76 1/3 feet in length and approximately 12 feet in diameter. The painting problem was successfully solved by installing a specially designed spray paint room which straddles the huge production line. This spray room is 91 feet long, and 42 feet wide, and reaches up to the roof trusses of the final assembly building. Two enormous olive drab, fire-resistant canvas curtains 90 feet long and 40 feet high, unroll like giant window shades on both sides of the room and complete the enclosure for the spraying process.

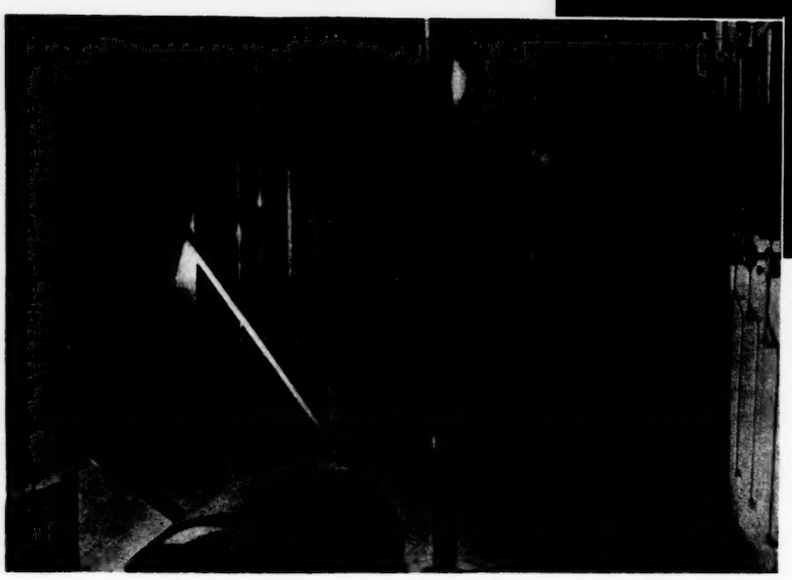
Air Replacement System

Atop the spray room at the nose end is the fresh air intake, or air replacement system, and above the water wash units at the tail of the plane are the exhaust blowers. The penthouse for the air intake system nests between the roof trusses of the skylight monitor where the air is heated, filtered and discharged downward into a vertical plenum chamber at the nose end of the plane.

Because of the limited space in which the installation is made, and for more flexible control, the system is divided into four equal units, each of which

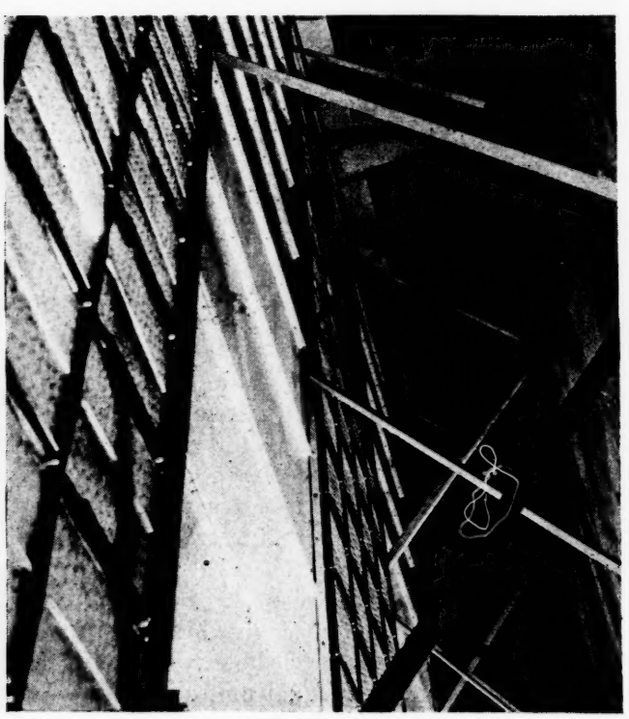
Fixed air intake louvers for the air replacement system, installed in the glass area of the monitor. →



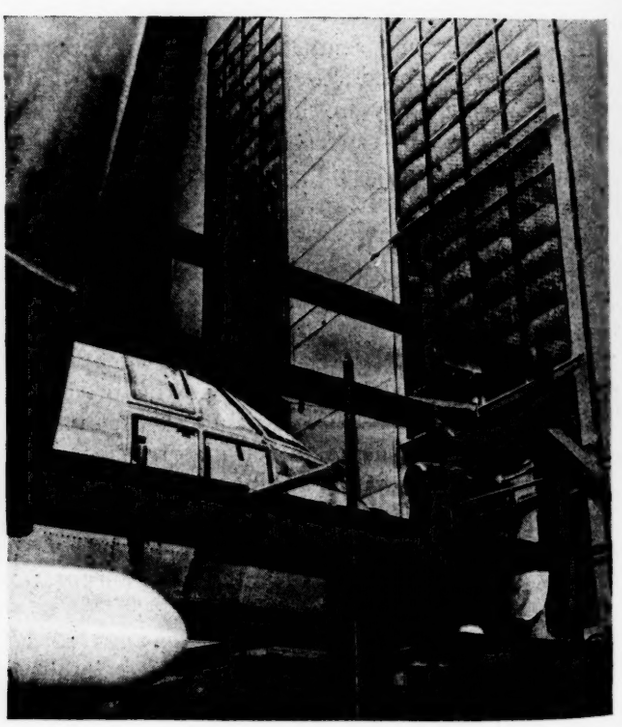


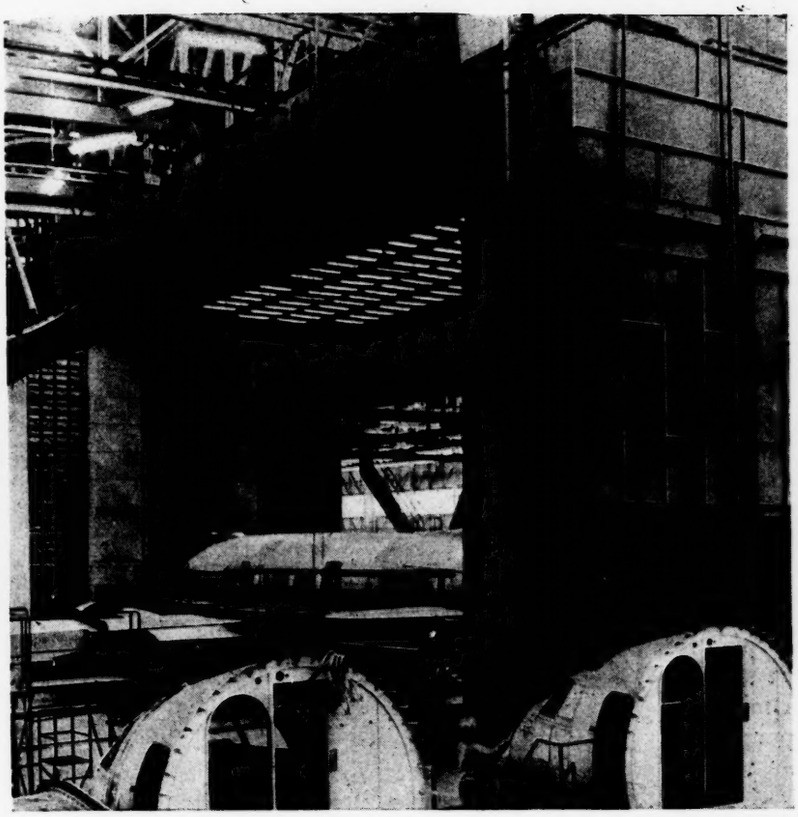
Inside one of the air replacement blower rooms, showing the "V" type filters and the entrance door from the access corridor. ←

Looking upward within the plenum chamber to three of the discharge openings from the air replacement blowers. The inside of the filter wall is also clearly shown.

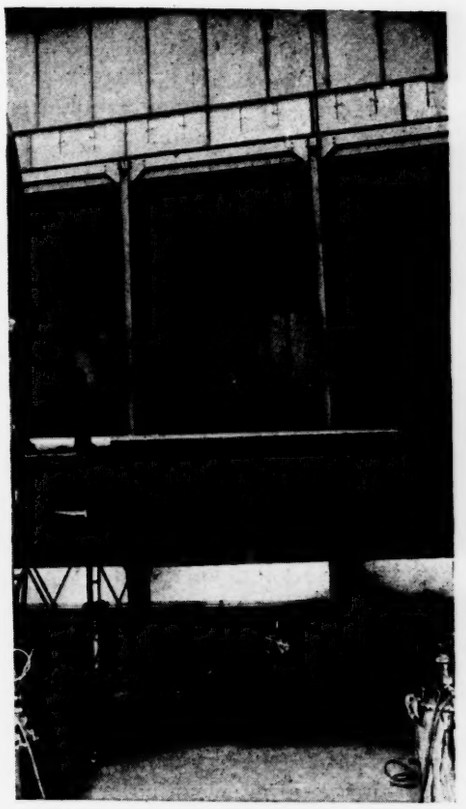


View of the air replacement plenum wall. Through the temporary scaffold can be seen the canvas connection which joins the 24-in. disc fan to the nose of the fuselage, to supply fresh air to the interior of the fuselage.

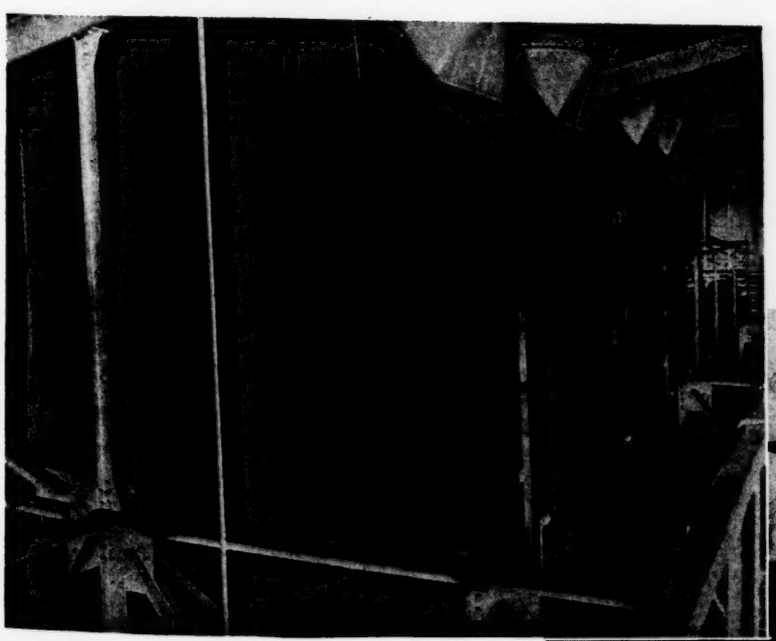




The giant spray room showing the secondary air filters installed in the wall of the air replacement plenum chamber. The backs of the water wash units are also visible showing the discharge pipe from the circulating pumps which delivers 660 gpm to the baffle plates over which the vapor-laden air is drawn by the exhaust blowers.



Water wash units, at the tail of the plane, remove the spray dust from the exhaust air. Four units circulate a total of 2,646 gpm which require four 15 hp motors to operate the pumps.



Four single width single inlet exhaust blowers exhausting the spray room through the water wall separator. These blowers are mounted in the skylight monitor approximately 60 feet above the final assembly working floor. ←

Exhaust blower discharge stacks through the roof of the skylight monitor at the Curtiss-Wright Corporation plant. →

may be controlled individually. In operation, air is drawn into the system through the monitor in which are located air operated shutters. They are opened when the manually operated blower circuit is closed, actuating a solenoid valve controlling the air supply to the shutters.

The incoming air passes through a double bank of steam coils. The preheat coil is thermostatically controlled and cuts in when the incoming air drops to 40F. The reheat coil is thermostatically controlled from the spray room and keeps 75F in the room.

After being heated, the air next passes through V-type dry filters of 42 cells, made up of three 20x25 1-in. filters. It moves on to the double width double inlet blower that discharges downward, delivering 45,000 cfm to the vertical plenum chamber. From this chamber air is distributed across the face of the spray room through a bank of dry type filters located in the plenum wall at the nose end of the cargo plane.

When all of the four units are in operation, there will be delivered a total of 180,000 cfm to the spray room, sufficient to change the air once each minute and so insure the complete evacuation of vapors and spray dust during the painting process.

Steam requirements for the heating of this air are substantial, for when the outside temperature dips to zero, it is estimated that approximately 18,000 pounds of steam will be required each hour to maintain the proper temperature within the room. In addition to removal of spray odors and dust, the heated air speeds the drying of the heavy pigment camouflage paint used on the transport.

Heating the incoming air is but half of the ventilation story, for the exhausting of the vapor and dust-laden air is equally important.

At the tail of the fuselage are four water wash units, each complete with its pump for circulating the water which cascades over the baffles and its large single width single inlet blower, mounted between the roof trusses, discharging to the outside through the roof of the monitor.

Here, again, each unit may be controlled individually as in the case of the supply blowers. When in operation, vapors are drawn through the curtain of water which resembles a miniature Niagara. The air is given a thorough scrubbing. All dust and pigment are removed, and settle in the circulating tank from where it is reclaimed and subsequently returned to the spray guns.

Because of the canvas curtains, it has been necessary to exactly balance the exhaust blowers against the air replacement blowers to insure a neutral pressure condition within the spray room.

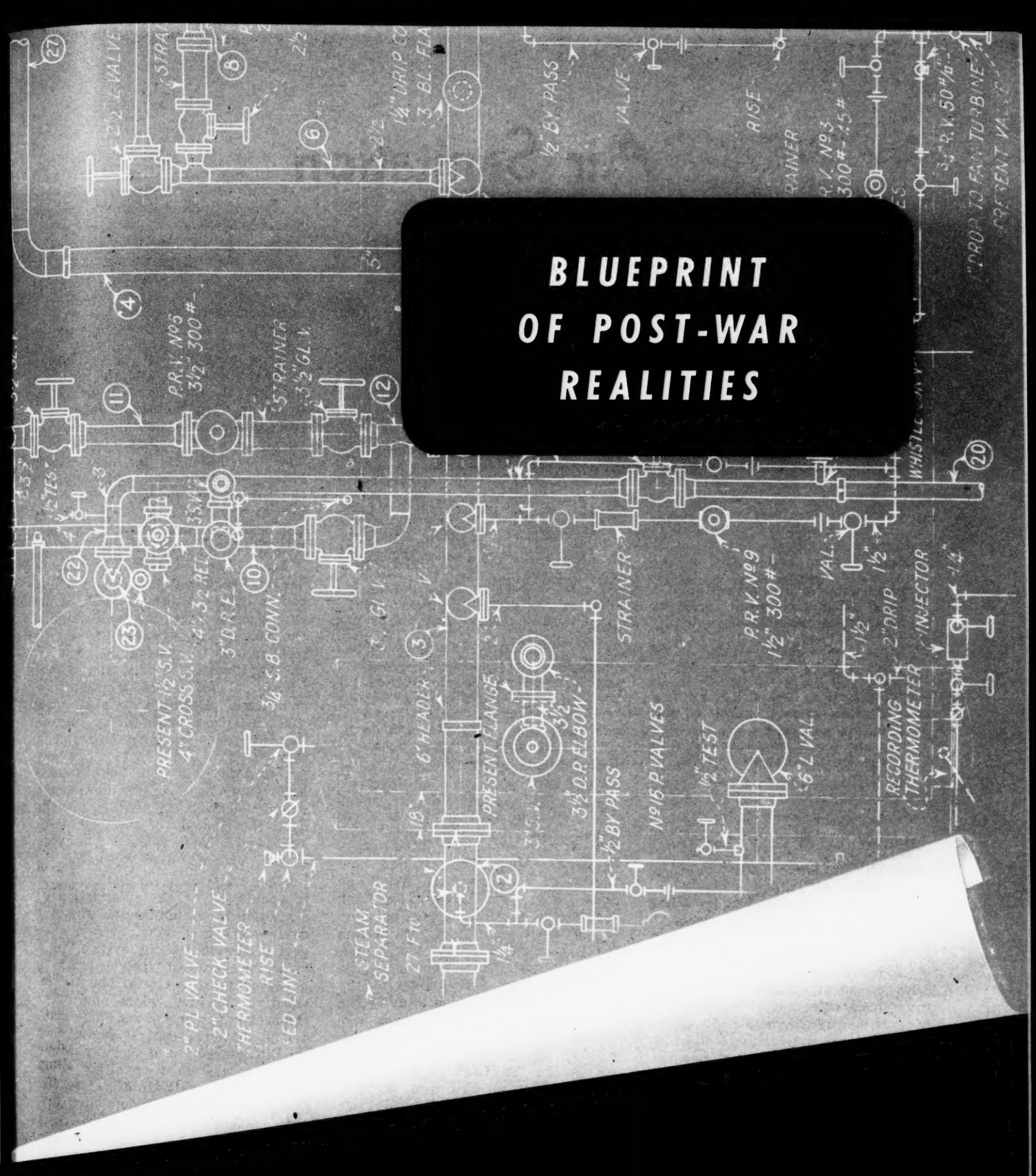
Another interesting feature is the supplementary air supply system to ventilate the plane interior. Connected directly to the fresh air plenum chamber, a flexible canvas connection is slipped into the nose of the fuselage. This connection surrounds a 2 hp 24 in. fan which picks up air from the plenum chamber and forces it into the fuselage in sufficient volume to establish a positive pressure. Much of the interior cleaning is performed in the spray room, and the cleaning fluid used has a noxious vapor which requires adequate ventilation. Also, the positive pressure within prevents the entrance of overspray.

Illumination Precautions

To provide adequate illumination for the painting of the Commando, there have been installed in the ceiling of the spray room a total of 194 48-in. 3-tube fluorescent reflectors which provide an exceptionally high level of illumination, comparable to a photographic studio. This makes it possible for workers to see all parts of the plane—on top and underneath —without the aid of supplementary light stands. It has done much to increase the speed and quality of the painting operation. Since the spray vapors are highly explosive, extra precautions have been taken to guard against any possible spark from a defective lighting fixture. Each of these fixtures is enclosed in a pressure tight box which has an air connection, and 5 pounds air pressure is maintained on all the lights. Should any glass crack, the pressure within prevents the entrance of any vapors.

This giant spray room is one of many special pieces of equipment which have been installed to speed the output of these large cargo-carrying Commandos in an effort to step up production for the Army. Many crafts and trades have combined their skills to make this production possible, and it can be seen that the science of heating and ventilating is sharing in this important work.

Partly responsible for the smooth running of the air conditioning equipment at the Hotel Statler, Washington, D. C., is Gladys Huffman, assistant engineer. Previously she had operated lathes and drill presses at the Washington Navy Yard. She has been at the hotel job for over a year.



AIR SANITATION

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The modes of air sanitation have not changed basically in more than a score of years, but in the post-war period fewer fields will present greater opportunities than the removal of atmospheric impurities.

Not only has removal of dust been considered a prerequisite in modern ventilation practice, but realization has gradually grown that control of odors and bacteria are of equal importance.

The field of application covered by the general term "air sanitation" is very broad indeed, but for purposes of this article we shall not consider the many-sided problems of modern industry. Our discussion will be limited to applications of a non-industrial nature, such as in offices, auditoriums, galleries, department stores, and homes. The principles outlined will, of course, have general application to any kind of ventilation system, so that nothing will be lost by the limitation imposed. As to the scope of this article itself, we shall include a critical survey not only of present-day equipment, but also the trends improvements and inventions will take. Quite naturally our discussion must include potential applications—that is, the probable market for application together with the necessary reasoning as to any conclusions reached.

There are two methods of approaching a discussion of air sanitation: (1) To discuss the fields of application in terms of dust, bacteria, and odors; or (2) to discuss equipment in terms of effectiveness for each field of application. The latter seems easier, because it avoids repetition when a single method possesses more than one attribute, and this will be the one followed here. But to clarify matters from the start, a brief outline will be given of just what is meant by atmospheric sanitation and the general methods available for control.

Significance of Dust, Bacteria and Odor Control

THE chief reasons for installing air-sanitation equipment in modern buildings are economic, although as in the case of bacteria and odors, other reasons may be more immediately apparent. While the benefits to be derived from such installations are frequently incapable of direct measurement, the causes leading to their adoption and general use are compelling. For example, large department stores are keenly aware of the depreciation in value of goods soiled by settled dust. These losses vary widely, but are of such magnitude that some thought must be given to reducing them. The control of such nuisance dusts represents the largest single argument for the widespread use of filters and other air-cleaning equipment. As to the economic background justifying the need for bacteria and odor control, more will be said later.

It seems best at this point to discuss some background relating to the scope and size of the average problem. Perhaps nothing more complete or even so up-to-date is available for this purpose than the excellent treatise prepared many years ago on the ventilation of subways by G. A. Soper (The Air and Ventilation of Subways, John Wiley and Sons, New York, 1908). This book deserves to be reconsidered, not only for the vast amount of information it contains on the subject of atmospheric contaminants, but also because no other text known to the writer has done so much to unify the science itself. Dr. Soper has discussed both economic and health aspects of the subject and has omitted none of the important variables. The data relating to dust and bacteria concentration in the air differ but slightly from similar data published in more recent years. The discussion of odors, particularly his efforts in tracing their origin in subways, and eventually relating them to public health, shows careful thought.

No further systematic studies followed Soper's investigations for several years, and in fact it was not until the end of World War I that practical applications of air cleaning (particularly dust control) came into being. Since that time there has been a rapid development in air sanitation until today most well designed systems of ventilation provide apparatus for cleaning air. In the industrial field a large amount of data accumulated on the effects of dust inhalation and the methods for control. But, as we have stated, in other than industrial fields control of air-borne contaminants was purely one of economic necessity. The developments in dust control have been important and will form the subject of another section. Suffice to say that the basic methods first used, remain those (with certain improvements) in use today.

Atmospheric sanitation pertains to devices required for removing air contaminants in any system of air supply or occupied space. Generally, the science of atmospheric sanitation applies to systems of mechanical ventilation, so that the airflow to any closed space is completely controlled. Although we shall show that there are methods for controlling air-borne bacteria independent of ventilation (and in fact can only function efficiently in such a manner), many bacteria are dust-carried and hence their elimination depends upon the removal of the dust itself. Thus, even bacteria control depends in part on controlled ventilation.

Since controlled ventilation is one prerequisite for the elimination of atmospheric contaminants, whatever devices are used must fit into some part of the ventilating system. As a rule, dust control systems may be used for most bacteria, but are ineffective against odors and may themselves produce odors. Some methods of bacteria control suffice only for the destruction of such organisms and have no effect on either odors or dust. The methods of controlling dust, bacteria and odors are discussed below.

Dust Control. There are four basic methods for removing dust from air. Only three of these are suitable for non-industrial ventilation, while all four may be applied in some form in industrial ventilation. They are (a) filtration, (b) electrical precipitation, (c) wet methods (as exemplified by spray methods), and (d) dynamic precipitation. Types (a), (b) and (c) are of general application, while (d), which concerns cyclones and other trajectorial means, is strictly an industrial application.

Filters are the oldest of the many ways of removing dust from the air. Efficient dust filters can also remove

air-borne bacteria, molds, and spores, but in general they are used to remove dusts of a nuisance nature. We shall discuss this aspect in the next section. Filters consist of porous media through which dust-laden air is made to pass, the suspended particles being impinged or enmeshed by the filter medium. Some filters are designed to collect dust in the form of a layer, that is, the bulk of the matter stays on the up-stream surface. This is characteristic of cloth, paper, and certain thin filters. Other types are thick and have a capacity within the medium to hold relatively large quantities of dust. These are generally constructed of metal-mesh, dipped with oil and drained before use.

The method of electrically precipitating dust has come rapidly to the fore during the past few years. Much of its recent success can be attributed to the use of lower voltages than formerly and to the introduction of "pre-ionization". Electrical precipitation is especially effective against fine particles and bacteria. Curiously enough, the rate at which air must be passed through this device is not much greater than that through the usual types of commercial air filters, but a higher efficiency is obtained.

Finally, there are so-called wet methods of air cleaning which consist of sprays or curtains through which air is made to pass. Spray chambers were formerly used extensively for air cleaning and even today are found in many installations. Newer designs appear to have eliminated the spray principle and consist of relatively porous filters over which water is made to flow. Such washers are most effective against nuisance dusts, and if there is no recirculation of water, odor difficulties are not as common as with the older spray chambers which provided only for the water lost by evaporation. When water recirculation is practiced there is often the chance that algae may form, giving rise to odors unless suitable treatment of such water is provided. One other difficulty common to wet methods of dust control is the fact that on warm days the humidity of the cleaned air may be raised somewhat, and this may not be desirable. So far as can be determined, no tests have been made with regard to the effectiveness of wet methods in restraining air-borne bacteria, molds, and spores.

Bacteria Control. Air-borne bacteria control is a development of very recent origin. However, it cannot be said that its essentiality is as recent; both Spallanzani in the 17th century and Pasteur in the 19th century appreciated its importance. And we may go back even further in point of time, for it is known that during the 14th and 15th centuries many people wore face pieces resembling birds, the beaks being filled with spices which acted as filters to destroy the imagined cause of disease. It is indeed remarkable that we should have waited more than 500 years to realize first that disease may be spread by the air we breathe, and secondly that such a thing as a mask (even though containing spices) could be used as a means of air purification, however inefficient it might be!

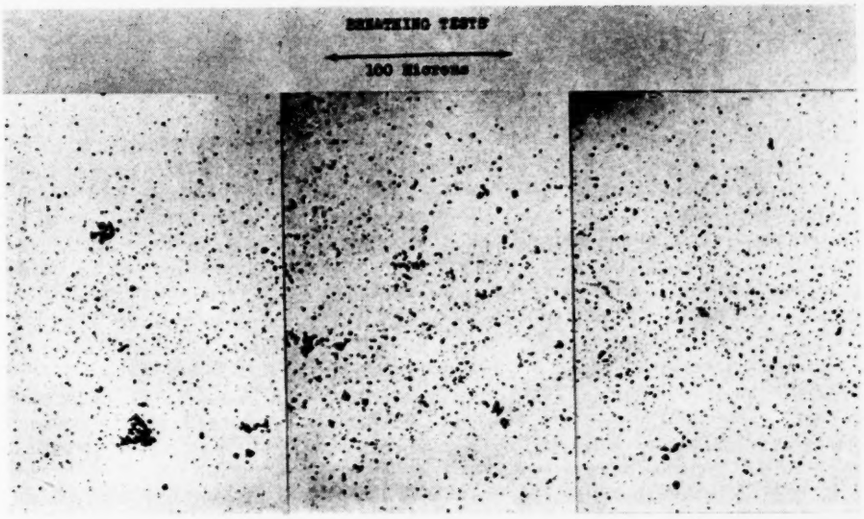

Fig. 1. Effectiveness of nose and mouth breathing in removing suspended air particles of the order of 2 microns and less. (Left) dust in air before breathing. (Center) dust in air inhaled and exhaled through mouth. Particles above 8 microns and some smaller particles were removed. (Right) dust in air inhaled through nose and exhaled through mouth. Particles above 3 microns and many smaller particles were removed.

With regard to air-borne bacteria, no extensive work was done until almost 25 years after Soper's researches. This does not signify that individual contributions are lacking, because an extensive literature is available for the interval. What is intended is that until the investigations of W. F. Wells during the last decade none of the information was correlated in a practical manner. In spite of the many difficulties hampering workers in this field—because its importance has never been fully appreciated, and its results never spectacular—Wells has succeeded in producing valuable engineering and epidemiological data and establishing the science of air bacteriology. Wells' papers should be read by all ventilation engineers, not only because of the results they contain but for his discussions which reach straight to fundamental problems facing research workers in the future.

We shall consider as bacteria any air-borne organisms. We have already indicated the suitability of some filters, and especially electric precipitation, in removing such organisms. In some ways it would appear that the latter method might be more effective than others to be cited subsequently, since many organisms are dust-carried. But again there is a paucity of information relating to the bacterial efficiencies of dust collection devices and it is not safe to hazard any estimate at this time. On the basis of experiments made a few years ago by the author, it would appear that bacteria-removal efficiencies are of the order of 60% of dust efficiencies obtained by A.S.H.V.E. tests of roughly 90%. But these tests are for droplets and not for dry bacteria, which are quite small and of all forms and types.

If there is any question today regarding the importance of air-borne bacteria, it should be dispelled by the competent researches of Wells and his associates. It is Wells to whom we owe most of the advancement made in air sanitation during the past few years. Perhaps his most remarkable contribution relates to the effectiveness of certain modes of air sterilization in controlling a serious epidemic of measles prevalent in the Philadelphia and Germantown schools during 1940-1941. During that year the incidence of measles in those areas was more than twice that of nine previous years combined. Yet the incidence in the grades provided with air sterilization by means of ultra-violet radiation was only one-third that in the non-irradiated grades, and of these almost four-fifths occurred before the air sterilization program was installed. Further studies, extending over a period of five years, on other childhood disease epidemics served to emphasize the value of air-sterilization.

There have also been other studies which confirm the value of air-borne bacteria control. These are the re-

sults of studies made in hospital operating rooms, infectious wards, and premature-rooms, and there are studies with reference to incidence of the common cold among employees in certain institutions which demonstrate the excellent results thus far achieved.

Certain aspects of air-borne bacteria control should be kept in mind. The benefits derived from control, like those of public health methods are not immediately evident. If the application is to culture rooms, results may be startling from the very beginning. But when we are concerned with large populations, records of the benefits derived—in terms of disease incidence—may often appear discouraging. It must be remembered that success so far achieved concerns controlled and disciplined groups, that is to say, groups of individuals whose daily activities are completely under the control of the investigator. This in no way alters the importance of results obtained, but it should be borne in mind that time spent in a "sterilized" environment is only a small fraction of the time spent in contaminated environments. The situation is similar to that of comparing the health of groups in air-conditioned and non-air-conditioned rooms.

In such studies there are so many variables beyond the control of the investigator that results often seem inconclusive, and yet no one can deny that there are many intangible benefits to occupants of air-conditioned spaces.

If proof be required that air-borne bacteria control is an important economic consideration one has only to question whether or not health has economic significance. For example, consider the incidence of respiratory infections such as the common cold. This infection is well-known to be spread by the air we breathe, and in any given group it is related to the degree of crowding. Some provision for its control, by reducing the number of organisms causing the infection, will not only be reflected in fewer chances of infection, but at the same time reduces the economic costs, both direct and indirect, caused by it. The amount of lost time in all occupations is probably greater for the common cold than for all other diseases combined, and considering also the discomfort and reduced efficiency of persons who are infected and continue work, the sum total of costs is appalling. A small reduction in this incidence would be worthwhile and more than pay for any equipment installed for controlling the infective agent. At the same time, as Wells and others have shown, the incidence of other contagious diseases may be reduced. Complete control of all air-borne infections is probably impossible and even undesirable, all things considered. However, it has been demonstrated that a significant reduction can be obtained, and this is well worthwhile. The usual argument that to spend money to hold down infections for eight hours a day, and then have personnel go where they choose so that infection cannot be controlled for the remaining sixteen hours, warrants little consideration. All things being equal, chances are that eight hours of control should reduce infections by almost a third. This is remarkable improvement, achieved by few drugs in the field of medicine.

Ultra-violet light is an effective germicidal agent. Unfortunately it has no penetrating power so that bacteria contained in droplets or in dust are often not completely destroyed. But it is valuable, especially in reducing the bacterial content of air to surprisingly low concentrations; and if, as many believe, infection is proportional to bacterial density and exposure, ultra-violet light is one of the best control means available, provided all the air supplied or the space occupied is thoroughly irradiated (often difficult of satisfactory accomplishment).

Use of chemical germicides, introduced into the air in the form of fine sprays appears to be quite effective. It lacks the confirming studies which ultra-violet has received chiefly because application of the chemical substances thus far proposed is in its initial stage. As in the case of ultra-violet irradiation bacteriological science has not yet progressed to the point of demonstrating whether a germicide is capable of destroying *all* bacterial forms normally found in air.

Odor Control. With the growth of air conditioning, the odor problems associated with high degrees of recirculation have assumed greater importance. Thus far the only practical means for controlling such odors is by use of activated charcoal filters. How effective this method of control is still remains to be seen. Unlike dust or bacteria, there is no absolute method for testing the effectiveness of an apparatus used for controlling odors. Tests depend upon subjective reactions of numbers of individuals to an arbitrary scale of odor intensities. Unless such tests are conducted in a thoroughly scientific manner little reliance can be placed upon the results obtained. Moreover, it cannot yet be determined when the adsorbers must be recharged or reactivated, except by subjective tests mentioned above.

Carbons other than activated charcoal are not very effective for odor

TABLE 1.—GENERAL CHARACTERISTICS OF USUAL TYPES OF COMMERCIAL AIR CLEANERS

Type	Collecting Media	Method of Cleaning	Dust Holding Capacity
Dry	Paper, Cloth Glass Fiber	Generally replaceable; of throwaway type. Some cleaned in place. Automatic types available, but media cannot be cleaned.	Low
Treated	Same	Same	Low
Viscous (oil or grease dipped)	Sinuous baffles, Crimped wire, Woven-metal mesh, panel flaps	Unit types removable for washing and retreatment. Automatic types made to dip into oil bath for cleaning and retreatment. Viscous filters are usually of permanent construction.	High
Electrostatic	Charged plates	Manual, or in automatic equipment by rotating plates in oil.	High

removal, nor do there appear to be other agents of equal effectiveness. Certain industrial gases and vapors, such as organic sulphides and mercaptans, require other means for removal or control, but these form another subject not within the scope of this article.

A few years ago much was made of the use of ozone for odor control. It was pointed out by Yaglou and others that while ozone is an effective oxidizing agent, it possesses intense odor-properties of its own which have a "blanketing" effect. However, the blanketing principle is widely used in odor control, especially to create sensations of cleanliness. This is accomplished by such substances as creosote, pine oil, etc. It need not be stressed that odor-control by such methods is not the same as odor removal with which we are concerned below.

Fundamental Considerations. The general equations covering the theory of filtration were developed by Underwood in Pickard's excellent treatise on filtration. However, the analysis given requires certain assumptions of a rather indefinite nature—that is, the equations utilize no information relative to the characteristics of the material handled. It remained for Hatch and his coworkers to develop a general equation covering all cases in terms of the size of particles handled and other measurable characteristics. In its simplest form the equation developed by these investigators is expressed as

$$h = k \frac{wv}{d^2} \quad \text{..... (Eq. 1)}$$

where h is the resistance in inches of water gauge, k a characteristic constant of the material collected and the fluid, w the weight of material on the filter surface, and d the diameter of the particles collected. The constant k may be broken down further into an absolute constant, a function of the porosity of the material collected and the density and viscosity of the fluid. In deep viscous type filters it is readily apparent that k varies and w takes on an equivalent value w'. However, with the customary rate of build-up in commercial filters it is assumed that k is constant, or very nearly so. It is given by the equation

$$k = k' \cdot \frac{\mu}{g\rho_0} \cdot \frac{1-f}{f^3} \quad \text{..... (Eq. 2)}$$

where k' in this equation is a characteristic constant of the collected material, μ and ρ_0 respectively the viscosity and density of the fluid, g the gravitational acceleration, and f the fractional voids or empty space in the layer of material lying on the surface of the filter, and the filter itself. In equation 1, f (which is the most important variable of the constant k) cannot be measured for many types of filters after they are in use by any means known at present. The ratio μ/ρ_0 is sensibly constant over the range of temperatures at which these filters are generally operated.

We shall return to fundamental Equations 1 and 2 below, but shall for the moment consider the general behavior of filters and the chief factors entering into their design and selection. The foregoing equations will serve to produce a clearer understanding of the reasons for present-day types of filters, as well as establishing a foundation for discussion of desirable types still to be developed.

For a given efficiency any practical filter must possess the following: (1) Low initial resistance to given airflow; (2) good permeability for a reasonable length of time after being placed in service; (3) ability to withstand temperature and humidity changes; (4) freedom from odors; (5) minimum fire hazard; (6) low replacement cost, or (6a) ease of cleaning; and (7) low maintenance costs.

At this point it may be indicated that in modern equipment these are, for the most part, embodied in three types of filters. All of these utilize a "restraining" medium for holding particles, and differ only with reference to design, materials used, and special mechanical features for cleaning. A rapid estimate of construction and a few general characteristics of commercial air filters may be obtained by referring to the data in Table 1.

Consider briefly some of the essential characteristics of modern air filters as outlined in the above paragraph. Low initial resistance and permeability are listed as the first two items. These are important because for a given efficiency low resistance and permeability mean (a) that more air can be passed through the filter for a fixed permissible pressure drop, or (b) that a larger reserve is available for pressure build-up by the dust collected. While most filters do not vary greatly among themselves as to initial pressure drop, some dry and viscous types show appreciable differences. Since horsepower consumed varies directly as the pressure, and the volume as the square root, it is readily seen that initial and final resistances of filters are important economic considerations. They also enter into the selection of fans having characteristics which will assure delivery of a constant volume of air over a wide range of resistance variation. For ventilation systems already in operation and to be provid-

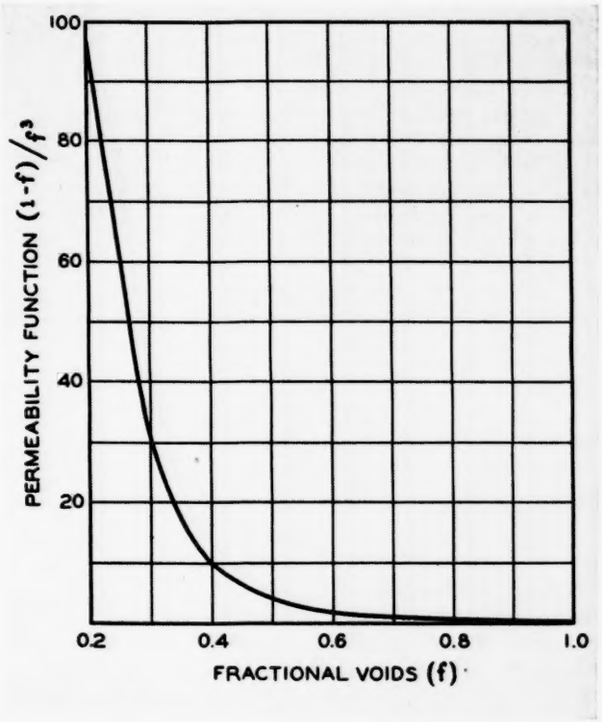

Fig. 2. Variation of permeability function $(1-f)/f^3$ with fractional voids F.

ed with filter units, the fan used may determine the choice of filter and its period of use.

The factor of permeability is new to air filtration and, we believe, is used for the first time in this paper. It is a better term than resistance when applied to thick filters, especially if we consider the medium and the material collected upon it totogether. The term may be defined in various ways—for example, the flow through one square foot of filter

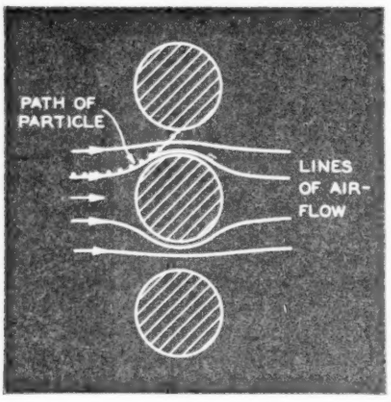

Fig. 3. Section of screen illustrating principle of mechanical filtration.

area, per inch of thickness, which with air at 70F will produce a pressure drop of 1 inch of water. However, in filter theory it is probably simpler to consider the term $(1—f)/f^3$ as the permeability (see Equation 2). In this term f represents the fractional voids which are readily determinable. The sensitivity of this index is apparent in Figure 2. Note how small changes in porosity affect the permeability, from which we conclude that any medium permitting rapid changes in porosity (voids) can have only limited application. The success of viscous-type thick filters is due to their inherent permeability, even after large amounts of dust have been collected in the void space.

Temperature and humidity do not appear to have any marked effect on the efficiency of filters within the normal range of temperatures at which they are used. In viscous or treated filters, high temperatures increase the vapor tension of the oil coating and give rise to odors, while in the replaceable types high humidities cause weakening of the supporting structure. However, in general, properly coated filters utilizing oils with good viscous and adhesive properties over a wide range of temperatures offer few difficulties. Odor problems necessarily appear as organic material builds up on the filter and begins to deteriorate, but good filter oils themselves are odorless, even at air temperatures as high as 120F.

Fire hazards are another matter. In some instances they may be spontaneous although it is not fair to say that viscous or treated filters are always more likely to cause fires than the so-called dry types. But once a fire is started the viscous types may be quite a hazard, although all things considered they are not necessarily more dangerous in themselves. When a large volume of air is moved through any filter the dust and organic material are rapidly oxidized and when they become lumped the local temperature may increase to such a point that a fire starts. The oils used in filters have very high flash-points, often greater than some of the organic material collected, so that in certain instances the oil may act as a protective coating. On the other hand, sparks or objects which ignite directly may prove more dangerous in the case of viscous than in non-viscous types.

We need not be too much concerned with mechanical filters—that is, with automatic cleaning or replacement of media. These are important, and have a bearing upon future filter design, but since here we are concerned only with the nature of filters, such features are secondary. Given a medium for collecting dust efficiently and possessing desirable resistance and permeability characteristics, the mechanization for cleaning or replacement can be derived rapidly.

Theory of Filtration. We have now arrived at the most important phase of our discussion. What makes a filter efficient? Analysis of this problem brings us to a discussion of some physical properties and characteristics of fine particles, as well as the media used to collect them. Following this we may be able to answer the questions posed and perhaps explain, at least in part, why some media so porous as to be transparent are more efficient than dense fabrics or other materials. Unfortunately, we can merely sketch the theory since complete verification requires more experimentation than has been done thus far.

Let us consider the most elemental type of filter: the wire screen. Obviously this can become a filter only if particles slightly larger than the openings are lodged in the interstices. Gradually, as the interstices fill up, the screen openings decrease in size and the material collected eventually forms a layer of progressively smaller pores. This may be termed "mechanical filtration." The only dust caught lodges in the interstices, with the impinged or interlocked particles thus beginning the formation of a collected layer. By referring to Fig. 3 we can see the reason for its low efficiency. This shows a cross-section of a fine wire screen and the manner of airflow through the mesh. Each wire acts as a barrier to the flow and there is a tendency for the wire to part the air stream. Thus, any particle moving with the air stream is suddenly subjected to a change of direction, the momentum causing it to leave the immediate vicinity of the wire and move toward the center of the interstice. Thus we may define mechanical filtration as the restraint of suspended particles by deflection so that they are collected by clogging or impingement and eventually form a layer which, in turn, further acts to restrain the movement of other particles.

The action of a screen (usually a series of expanded metal sheets) found in many types of viscous filters (placed on the upstream side) is similar to that described above, and is designed for restraining the largest particles which may be in the air. While it may appear that filters using expanded metal screens (provided with openings often as much as 1 in. x ⅛ in. in size) are not true mechanical filters of the type described above, nevertheless they actually are similar since these expanded metal screens become barriers or baffles deflecting the flow and cause the particles to change direction and impinge on a collecting surface, the action thus conforming to our definition.

Under the classification of mechanical filters we may include all viscous types constructed of metal, coarse glass fiber, or other non-ferrous media, as well as materials which act as screens such as glass and asbestos fabrics. Not included in this group are wire-flock filters whose principle of operation is similar to that described in the next paragraph.

There are filter media, such as wool and some loosely constructed felts, paper tissues, finely spun glass fiber in thin sheets, and flocked wire screen, which do not seem to behave in the same manner as mechanical filters. In these fibrous and highly permeable types we find a different mechanism consisting of two things: (1) A particle-restraining action with relatively little local deflection of air currents, and (2) electrostatic

attraction. These filters are quite thin and are characterized by their fibrous nature. There are no true pores or orifices, consequently less localized "crowding of the approaching air." Even in woven media, excepting glass and asbestos, the air passes through the spun threads after the interstitial areas are filled.

The action of the media just described is a surface phenomenon. With a very small area and slight depth of filter there is much more exposed surface than is possible for corresponding conditions in filters we have classed as mechanical. It is a question of the number of individual fibers, even though they are of small diameter. Of course there is a limit; in dense felts, for instance, we have an orifice-effect developing rapidly after dust collection begins. In "true filtration," as the present action may be described, the particles adhere to the surface of the fine fibers, delaying the build-up of resistance. Small particles pass through only because in such filters there are many direct openings from front to back, and these are large compared with cross-sectional areas of the particles themselves. However, a larger percentage of small particles will be caught than in filters based on impingement principles.

As is well known, any surface phenomenon is often closely associated with electrostatic activity. The passage of air through material composed of a dielectric creates a charge on the exposed surface. The polarity of this charge depends upon the medium, but it is evident that particles oppositely charged and moving with the air stream will be deposited on the dielectric surface. In turn, if the particles are also dielectrics they will receive a new charge after collection and a complex electrostatic action will take place as particles continue to build up on the filter surface. However, after a certain amount of particles has collected, the surface of the filter begins to form small pores and the mechanical action overcomes the surface and electrostatic actions, and we have a mechanical filter. On damp or humid days, when the relative humidity exceeds 60 per cent, the electrostatic activity of the above filters is quite small and their efficiency lessened. Table 2 shows the charges assumed by various particles blown through a brass tube.

From a large number of experiments with a wool medium, conducted by the author a few years ago, it was observed that true filters have a linear rate of resistance build-up which continues much longer than with mechanical filters, for corresponding dust loads. This observation is suggested as a possible means for differentiating the two classes of filters above discussed.

Filter Resistance. We now return to a discussion of Equations 1 and 2. Good efficiency, while a most important prerequisite of any filter, is actually secondary to resistance build-up. The reason is due to the limitations of the fan and the cost of operation, which will be discussed more fully later. Ventilating fans are usually designed to operate efficiently against a fixed resistance. If the resistance in a system varies, as is the case when it is equipped with filters, there can be a very large decrease in air volume handled due to the increase in filter resistance. In turn this affects any cooling or heating equipment forming a part of the ventilating system. Hence, filters must be designed and maintained in such a way that the resistance build-up conforms to the characteristics of commercial fans—that is, in such a way that the air volume changes as little as possible.

Efficiency of collection must often be sacrificed in order to achieve this condition. The introduction and widespread use of self-cleaning or replacement units is to keep the resistance build-up below a predetermined limit.

In Equation 1 the constant k (defined as in Equation 2) is a function of the porosity only if our discussion concerns air at a given temperature. However, as already stated, the porosity (and hence, the permeability) cannot always be determined for any filter. From Fig. 2 it is clearly evident that any small change in f causes a very great change in permeability. This change is most marked within the design limits of filters, that is, at porosities less than 0.5. Thus, since f cannot usually be determined when the filter is in place, and since any disturbance of the medium will have an important effect on the permeability, we must assume that during the normal course of operation k is substantially constant. If it is necessary to consider k as variable, then for a constant velocity and particle concentration we have with respect to time t from Equations 1 and 2 expressed as follows:

(Eq. 3)

$$\frac{dh}{dt} = \frac{k'\mu}{g\rho_o}\left(w\frac{dk}{dt} + k\frac{dw}{dt}\right)\cdot\frac{v}{d^2}$$

Now w is a linear function—that is, if the dust load is constant and v does not vary, $w = Cqt$ where C is the concentration per cubic foot of air and q is the volume of air passing through one square foot of the filter surface ($= v$). Hence, the above equation reduces to

(Eq. 4)

$$\frac{dh}{dt} = \frac{k'\mu}{g\rho_o}\left(t\frac{dk}{dt} + k\right)\cdot\frac{Cv^2}{d^2}$$

Similarly, as a first approximation, k may be assumed to vary linearly with time, $k = k_o + k_1 t$, where k_o is the initial permeability and k_1 the permeability increment at any subsequent time t. The initial permeability is easily determined, but k_1 can only be estimated. For example, a typical value of porosity suitable for calculating k_o is 0.5, while for k_1 it may be roughly 0.3. By substitution in Equation 4 and integrating from $t = 0$ to $t = t$ we have

(Eq. 5)

$$h = \frac{k'\mu}{g\rho_o}\left(k_1 t^2 + k_o t\right)\cdot\frac{Cv^2}{d^2}$$

This gives the value of h at any time t, in terms of the dust load. The value of k' may be taken as 0.2 if the units are in the cgs, and h is expressed in cm of the fluid. Therefore, for a fixed velocity and material collected by the filter we see that h is a parabolic function of time, which conforms with experience. Note that $k_o t$ is small as compared with $k_1 t^2$. Hence, we may write

$$h = \frac{k'\mu}{g\rho_o}\cdot k_1\cdot\frac{Cv^2t^2}{d^2} \quad \ldots(\text{Eq. 6})$$

The previous discussion illustrates

TABLE 2.—NET CHARGE ACQUIRED BY BLOWING EQUAL VOLUMES OF VARIOUS SUBSTANCES THROUGH A BRASS TUBE

Material	Charge on Tube	Charge on Cloud
Borax	+	−
Sodium bicarbonate	−	+
Lime (CaO)	−	+
Fused quartz (SiO_2)	+	−
Ammonium chloride	+	−
Sodium carbonate	+	−
Sodium fluoride	+	+

all the variables of significance in determining filter resistance. Since, as we have shown, there are many difficulties inherent in the determination of k, and also since the ratio μ/ρ does not change materially during the usual operating temperatures, we may lump most of the constants and utilize an equation due to Williams and Hatch:

$$h = \frac{KCv^2t}{7000} \quad \text{.....(Eq. 7)}$$

which is easily derived from Equations 1 and 2, and from the relation $w = Cvt$ in units subsequently given. Thus, K can be determined from experiment. If h is expressed in inches w.g., C in grains per cu ft, v in lfm, and t in minutes (the time required for the filter to increase h inches w.g.), then K for any given dust is the specific resistance in inches w.g./lb dust/sq ft filter area/lfm filtering velocity. Values of K for various dusts according to particle size are shown in Table 3.

A close examination of this table illustrates the effect of particle size, but not the effect of permeability. However, it does serve to show why filter resistance builds up rapidly when fine particles such as lampblack and zinc oxide are collected. Unfortunately, no data are available for evaluating K when outdoor air is passed through filters. The diameter must then take on some average of the distribution of sizes, but it must also be clear that the value of K obtained will depend on the kind of dust collected which, as is well known, varies with locality.

Filter Efficiency. Within the space allotted to this article we cannot hope to discuss the many-sided problems of determining filter efficiency. For this the reader should refer to the numerous contributions by Rowley and Jordan in the Transactions of the A.S.H.V.E. during the past few years. Efficiency is defined simply as the ratio of the amount of dust collected by a filter to that in the air stream passing through it. But from a practical viewpoint it is clear that there is more than this involved. Rate of resistance build-up, holding capacity, filter life, and other items are equally important, and it is probably preferable to have some other means of designating efficiency than that now used. "Performance" would be a better term if it could be established by some index. At the present time the term "efficiency" connotes little if any information, except as a means for comparing the relative restraining abilities of various filters tested in accordance with a standard procedure. Yet it is an incontrovertible fact that few designers know exactly what is wanted in the way of dust removal. Hence, no one test can stipulate what a filter will do in practice, unless it is applied to industrial dusts. So far as the writer is aware, there has never been a correlation of standard test data with data obtained after filters were installed. Therefore, we may state that thus far (a) standardized efficiency tests are suitable for comparing the relative restraining qualities of various filters, and (b) data are needed to establish the degree of air cleanliness desired on the downstream side of filters.

Let us concentrate on the second of these two statements, since the first is generally understood and requires no discussion. Figure 4 shows microphotographs of suspended dust taken from the upstream and downstream sides of four air filter installations. The dust load is about that normally found in the outdoor air of any large American city. Note that particles above 10 microns are not seen and that the average size we must contend with removing is of the order of 2 microns. Note further that for this size range the viscous-type filters (Figs. 4a and 4b) and the spray-type air washer (Fig. 4c) have no restraining ability, but the wool-felt filter (Fig. 4d) is quite effective. These microphotographs do not show particles larger than 5 microns because such particles settle quite rapidly in air and are not as numerous as the smaller sizes. As a matter of fact the frequency of particles as large as 2 microns has been shown by many investigators to be less than 1%. However, these data are for number in any given sample. Efficiency is based on a ratio of *weights*. This affects efficiency very markedly since mass varies as the cube of the size. A particle of 100 microns, which is not uncommon in outdoor air during a windy day, will weigh as much as one million particles one micron in size. Again, if covering-power of particles is to be considered, it is evident that the finer particles are more important in the ratio of $10^6 \times 1/1 \times 100^2$ or 100 times, since surface is as the square of the diameter.

We have discussed the above in order to illustrate possible misunderstandings in using the term "efficiency", and also to show the importance of particle size in interpreting results of efficiency tests. It is not the intention to criticize existing test methods, but rather to emphasize the importance of knowing what

TABLE 3.—FILTER RESISTANCE COEFFICIENTS (K) FOR CERTAIN INDUSTRIAL DUSTS (INCHES W.G. PER LB DUST PER SQ FT CLOTH PER LFM FILTERING VELOCITY)

Dust	Particle Size						
	Coarse			Medium		Fine	
	20 Mesh	140 Mesh	375 Mesh	90 Microns	45 Microns	20 Microns	2 Microns
Granite	1.58	2.20				19.8	
Gypsum			6.30			18.9	
Feldspar			6.30			27.3	
Lamp black							47.2
Zinc oxide							15.7
Resin (cold)		0.67				25.2	
Oats	1.58			9.60	11.0		
Corn	0.62		1.58	3.78	8.80		

gets through a filter in terms of size and frequency of the various particles. We need only refer to Fig. 4 to realize that from the standpoint of number and size, viscous filters show a low efficiency. Yet in terms of weight the efficiency of these filters is within 10 per cent of the felt-type, which would be considered to perform excellently.

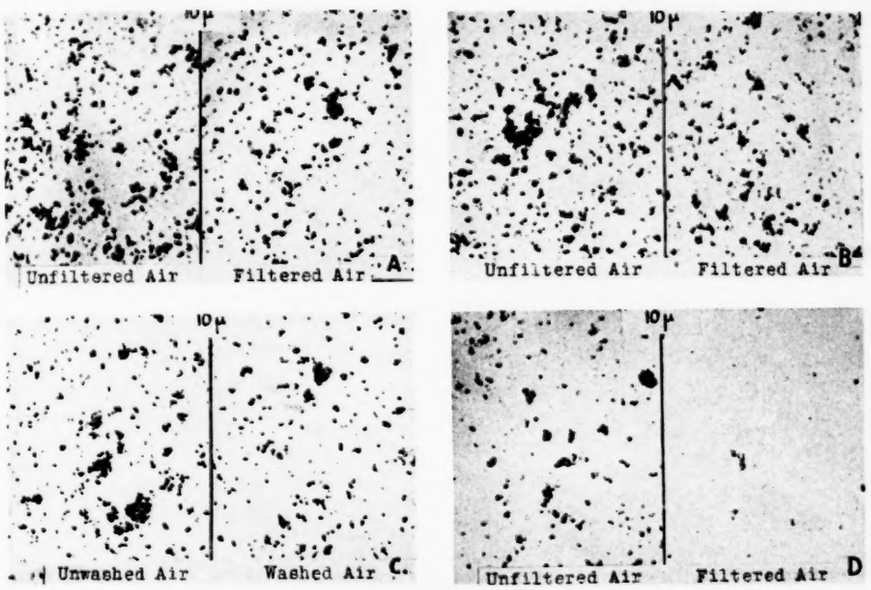

Fig. 4. Microphotographs of dust entering and leaving filters. (a) and (b) metal, viscous-coated filters; (c) spray washer; and (d) thick, virgin-wool felt.

As a corollary to the above it follows that different filters have different applications. This is a fact which filter manufacturers have emphasized repeatedly, and explains why so many types are found on the market. The manufacturer has learned from experience what each problem requires and, as we shall show, often sacrifices efficiency by usual test procedures because a particular problem calls for removing a high concentration of particles of large size. Actually, under field conditions, it is conceivable that a filter with a low efficiency in terms of numbers restrained may approach 100% efficiency on a weight basis. But this is determinable only from experience and is not a hard and fast rule. The purchaser usually requires tangible evidence. The writer believes that with a growing public recognition of the importance of air cleaning, more and more emphasis will be placed on the material getting through filters rather than on "efficiency" in the sense it is now used. It will be necessary to understand better just what is in the air and what criterion of air cleanliness is desirable.

The term "performance" was employed in an earlier paragraph as being a better term than "efficiency" for describing the goodness of a filter. We have stressed the importance of resistance rise and restraining power (efficiency). Holding capacity is another variable. At present, there is no way of rating the latter property, which is also related to cleanability (in the case of permanent filters), and "life" of throwaway types. Resistance governs holding capacity to a large extent, since it is the ultimate criterion for determining when a filter should be cleaned or thrown away. Some effort must be applied to correlate these three filter characteristics (efficiency, resistance, and holding capacity), and establish an overall index of performance. We cannot long continue to believe that efficiency is the *only* item worthy of a standardized rating method. Rowley and Jordan, who contributed a great deal to the subject of filter rating, from their writings appear to be giving more and more attention to a concept of performance very much along the lines just discussed.

The foregoing remarks concerning efficiency (with regard to dust) may seem unfair, especially in view of our present knowledge on the subject. However, air sanitation has progressed sufficiently far that to delay a comprehensive examination of efficiency (or performance, if we choose this term) will definitely affect development and eventually force possible users to decry the emphatic claims made by manufacturers for certain of their products. In industrial dust control recognition has been given the desirability of meeting given standards of air cleanliness, and these are absolute. Attempts to break down these standards by substituting terms such as "best engineering practice" never alter the basic fact that dust diseases are related to dust concentration. While we are not concerned with any health problem in this discussion, nevertheless the point is pertinent. In the final analysis, with increasing public interest in air sanitation it is inevitable that we must establish some standard or standards of air cleanliness in the very near future.

Most Economical Filter Velocity

Determination of the most economic filtering velocity is exceedingly difficult. One has only to refer to a discussion by Rowley and Jordan (Trans. A.S.H.V.E. 1941, pp 391-402) to fully appreciate their wide complexity.

We shall not attempt a thorough analysis of the subject because, everything considered, no data are available other than those dealt with by Rowley and his co-workers. Our discussion will be over-simplified and the result may be regarded as a first approximation. We shall follow Lord Kelvin's procedure for determining the most economical size of electrical wire for a given load, and begin by stating the assumptions leading to the solution.

First of all, we assume that costs are predicated on a filter-area basis. Thus, the initial cost, including installation, will be say p_1 cents per sq ft, and retired in n years. The cost of replacements will be based on the fractional area of new filters replaced each year. Let the turnover be c sq ft per year, and p_2 the cost per sq ft of filter. Hence the cost of replacements is p_2cA for the whole system, where A is the total area. The maintenance charges may also be figured on a unit area basis. Let this cost be p_3 cents per sq ft per year. Finally, there are power costs—that is, the cost of energy consumed in moving the air through the filter. Let this be p_4 cents per kilowatt hour. This last is the only term requiring

slight elaboration. If energy is given by the expression $E = 0.000117\ Qh$, where Q is the volume of air moved through the system and h the pressure drop in inches of water, then for T hours per year of operation the cost of energy is $0.000117\ p_4QhT$. We now require an expression for h. Let us assume that to a fair degree of approximation the pressure drop is proportional to the square of the velocity—that is, $h = kv^2$ where k is a constant and v the approach velocity of the air through the filter. Hence $h = kQ^2/A^2$.

Now from the above we assume that Q (the volume of air) does not vary much with resistance build-up. In other words, we assume a fan with such characteristics that a change in h gives rise to a negligible change in Q. This is usually the case where filters are properly maintained, and the system is well designed. Let the cost of power, when h varies as the square of the filtering velocity, be given by the expression $0.000117\ p_4kTQ^3/A^2$, where p_4 is the cost per kwh. Therefore to summarize, we have the following:

1. Cost of filters and installation $= p_1A/n$ cents per year
2. Cost of replacements $= cp_2A$ cents per year
3. Maintenance charges $= p_3A$ cents per year
4. Cost of power $= 0.000117\ p_4kTQ^3/A^2$

The total charges per year for the filter is

$$P = p_1A/n + cp_2A + p_3A + 0.000117\ p_4kTQ^3/A^2$$

To obtain the velocity, for which P is minimum, differentiate this expression with respect to A; setting it equal to zero and remembering that $Q/A = v$ we get

$$\frac{dp}{dA} = p_1/n + cp_2 + p_3 - 0.000234\ kTv^3 = 0$$

Hence

(Eq. 8)

$$v = 16.2\left(\frac{p_1/n + cp_2 + p_3}{kTp_4}\right)^{\frac{1}{3}}$$

We may now illustrate by means of an example. Suppose that replaceable filters are used and that their initial cost, installed, is $6.24 per sq ft. If 10 years' depreciation ($n = 10$) is allowed, this cost per year is 62.4 cents per sq ft. The cost of each filter replacement is 37 cents per sq ft, and if these are replaced 4 times each year ($c = 4$), the replacement cost is 4 x 37 = $1.48 per sq ft per year. Maintenance charges are conservatively estimated as 2 cents per sq ft per year. Determine the most economical air velocity if the cost of power is 1.7 cents per kwh, and the filters operate 2000 hours per year.

The constant k must be estimated from experimental data. Let $h = 1.1 \times 10^{-5}\ v^2$, so that $k = 1.1 \times 10^{-5}$. Substituting the values of the unit costs and other data above in the expression for v, we have

$$v = 16.2\left(\frac{62.4 + 148 + 2}{1.7 \times 1.1 \times 2 \times 10^{-2}}\right)^{\frac{1}{3}}$$

$$= 290 \text{ lfm} \qquad Ans.$$

Electrostatic Precipitation

The future of air cleaning will probably hinge more on the further development of electrostatic precipitation than on any other device in use at the present time. The principle involved and its applications contain all the attributes so much desired in dust control systems. The method is highly efficient, more so for fine dust and bacteria than any other known means, and possesses very low resistance to the flow of air. Some perfections in design and operating details remain to be worked out. We shall discuss these later, but thus far it is safe to state that electrostatic precipitation affords the only available means of obtaining air practically particle-free.

Theory. When a particle moves in an electric field with streamline motion, the resistance encountered is given by the equation

$$R = k\mu vd$$

where μ is the viscosity of the air, v and d the velocity and diameter of the particle respectively, and k a constant which for spheres is 3π. When the motion of the particle is steady, this resistance is countered by the force of the electric field, Ene, where E is the voltage gradient and n the number of unit charges e on the particle. Hence, for a spherical particle

$$3\pi\mu vd = Ene$$

$$v = \frac{Ene}{3\pi\mu d} \qquad \text{(Eq. 9)}$$

This equation states that the velocity is directly proportional to the strength of the field and the charge on the particle (ne), and inversely proportional to the diameter. To determine the path of the particle we have $v = dx/dt$, where x is a linear coordinate, and $E = V/x$, where V is the voltage applied between the terminals of the field, so that

$$\frac{dx}{dt} = \frac{ne}{3\pi\mu d} \cdot \frac{V}{x}$$

and integrating from $x = 0$ to $x = x$, and $t = 0$ to $t = t$

$$3\pi\mu dx^2 = 2Vnet$$

If the air (and the particle) is moving along a y-coordinate with a velocity v' then $y = v't$, so that at the time t, from an arbitrary initial position and time $t = 0$

$$3\pi\mu dv'x^2 = 2Vney$$

$$y = \frac{3\pi\mu dv'}{2Vne} \cdot x^2 \qquad \text{(Eq. 10)}$$

so that the path is parabolic. This equation serves to determine the dimensions of the plates or other geometrical arrangement so that the particle is completely precipitated, providing of course that ne is constant and is not a function of time.

Now all the quantities in Equation 10 are known except ne, the amount of charge taken by the particle, which is a function of the time the particle remains in the field. This charge may be calculated by an expression due to Pauthenier, as follows:

$$ne = \left[1 - 2\left(\frac{k-1}{k+2}\right)\right] \cdot \frac{\pi d^2 ti}{4} \cdot \left(\frac{1}{1 + \pi ti/E}\right) \qquad \text{(Eq. 11)}$$

where k is the dielectric constant of the particle, i the current density, and other terms as previously defined. Equation 11 above gives the amount of charge accumulated by

the particle in the time t. When the particle is a conducting sphere the bracketed expression is equal to 3; (note that when t is very large the last term in parentheses approaches one). The insertion of the above equation for ne in Equation 11 and its use in deriving an explicit relation for the path of the particle result in an expression of some intricacy. In the above equations x and d are measured in cm, t in seconds, and E and i in esu.

Practical Aspects. The first application of electrostatic dust precipitation was made by Oliver Lodge almost 60 years ago, but its widespread industrial use dates from the second decade of the present century, following experiments by Cottrell with sulphurous acid mist. It may be said that the successful use of electrostatic precipitation had to await the development of necessary electrical apparatus, notably transformers and rectifying equipment.

The Cottrell precipitator has been employed chiefly in power plants for collection of fly-ash. High voltage gradients are used and a relatively large amount of ozone is produced, which limits any application to ventilating systems. Briefly, the basic design of the Cottrell system is as follows. In the cylinder type, the potential is applied between an axial wire and a metal cylinder. Dust-laden air or gases are made to pass through the cylinder and the suspended particles are precipitated on its inside surface. As often as required the air is shut off and the cylinder rapped, causing the dust to fall into a hopper. In the plate system, the dust-laden gases pass between a series of parallel plates, every other one of which is positively charged, and those in between are negatively charged. These plates are rapped at suitable intervals as in the case of the cylinder-type already described.

In precipitators used for ventilation, sub-corona voltages must be used to avoid ozone production as much as possible. In the so-called precipitron and related devices the following arrangement is used: Preionizing wires of very small diameter are charged to a positive potential of approximately 12,000 volts. These wires are mounted vertically between streamlined struts which are grounded. The spacing of wires and struts is such that the gradient is below that at which corona is produced, and ozone forms only in minimal quantities. The diameter of the ionizing wire, its spacing, and location with reference to the struts, are critical. Of these variables it has been found that wire diameter is most important and that sizes above a specified limit produce ozone in detectable amounts.

The preionizing wires create a heavy stream of positive ions which attach to the particles of dust in the air passing them. Thus, almost all the dust is positively charged before it reaches the charged collecting plates. The latter are charged in the same manner as in the Cottrell plate system, but employ potentials of the order of 6000 volts. Thus the plates may be placed more closely together and at the same time the production of ozone is nil. Since the preponderance of dust particles reaching the plates is positively charged, these are deposited on the negative or grounded plates and there is very little counter-movement of particles moving toward opposite polarities.

In the electrostatic precipitators and related apparatus described before, electronic rectifiers (called power packs) are used. These have rendered the precipitator into a compact unit, which together with the absence of ozone production have made it a most useful device for the collection of air-borne dusts and bacteria. When properly operated, no other means of dust collection attains the same degree of efficiency.

While in principle the electrostatic precipitator possesses attributes which cannot be attained in filters or other collecting devices, its present state of design leaves much to be desired. In the paragraphs to follow we shall point out some of the limitations of electrostatic precipitators. No generalizations will be made other than to cite common practical difficulties. Furthermore, it must be remembered that most installations, when properly designed and operated, give excellent service. Difficulties arising are frequently not as serious as those associated with ordinary filters, and we should not be too prone to believe that a particular dust problem could be dealt with more easily by other means. The chief value of the electrostatic precipitator is the fact that no other air cleaning device can approach it in efficiency, this more often than not being the only reason for its selection. (We shall have more to say about this later.)

The most serious drawback to electrostatic precipitators is the need of an adhering surface to which the particles will cling. Once a particle has been precipitated on a bare plate there is always a possibility that the air flow will release it and carry it beyond the device, thus reducing cleaning efficiency. This difficulty is usually overcome by coating the collecting plates with oil or thick petrolatum. In automatic cleaning devices the grounded plates are made to revolve and eventually dip into a bath of oil where the accumulated dust is sloughed off. In designs using stationary plates, a petrolatum is applied. The use of these substances, while effective in holding the dust once it has been precipitated, provides a potential fire hazard. In any electrostatic precipitator it is difficult to hold down sparking or arc-over, and although the electric circuits are so made that power arcs can be maintained for only a small fraction of time, nevertheless fires have been caused through failure of some part of the equipment, resulting in extensive damage. Thus, close attention to fire hazard must be maintained at all times.

Two other faults must be mentioned. The first is breakage of preionizing wires, due either to build-up of material on them or to the force of the electrical arc-over which often takes place. Since the efficiency of dust collection depends upon the preionizing wires being intact, they must be inspected at regular intervals.

The second fault concerns the small percentage of positively charged particles which escape from the unit. Thus far this difficulty has not been remedied completely, although a method for its control was recently patented and may show promise. The positively charged particles escaping the electrostatic precipitator tend to remain in suspension after leaving the ventilating system, collecting on the walls and ceilings of the room into which the air is moved. In other words, the particles do not settle like ordinary dust, but discharge on any surface which has an opposite polarity. Considering the large volumes of air handled, and the usual turbulence occurring in any closed space, it is not long before the walls become discolored. And this happens in spite of the high efficiency of the electrostatic device, which well illustrates the "covering power" of fine particles already discussed. It must be mentioned, however, that this phenomenon does not occur in every installation, and it is probable that the device is not solely to blame.

Precipitator Efficiency. Deutsch developed an expression for determining efficiency of electrostatic precipitators of the Cottrell type. This takes the form

$$\frac{C_o - C}{C_o} = 1 - \exp\ (-kvL/Rv_g)$$

where C_o is the concentration of suspended matter entering the device, C the concentration leaving it, v the velocity of the particle along the lines of force (see Equation 9), L the length of the collecting surface, R the distance between electrodes, v_g the gas velocity, and k a constant. The value of k for a wire-in-cylinder collector is 2, and for a wire-to-plate collector is 1. Unfortunately, no equation is available at present which applies to the preionizer unit.

Electrostatic precipitators are not efficient in collecting large particles possessing considerable momentum, nor are they efficient when the dust concentration is high. Inefficiency in the latter case is probably due to collisions between particles and possible failure of the preionizing wires to charge all the particles. Repulsion effects may also be quite marked and even the electric fields may be affected. However, any upper limit of dust concentration depends to a large extent on the nature of the dust in the air stream, and therefore it is not possible to specify the maximum amount of dust which may be handled. As to any failure to collect large particles, it is obvious that the air velocity must necessarily influence the condition. Most electrostatic precipitators employ air velocities ranging from 350 to about 500 lfm, velocities which are of the same order as those used in filtration. Higher velocities are possible if the length of field traversed by the air stream were increased, but this is fixed by space considerations and other factors.

The largest percentage of dust particles found in outdoor air is below 2 microns in size, as may be seen by reference to Fig. 5. This is well within the range for which the electrostatic precipitator is most efficient. The nature of the distribution will of course vary from place to place, but it is rare indeed, except during windy days or during dust storms, when suspended particles exceed 5 microns in diameter. Particles of this size settle fairly rapidly in air. Some idea of the rate of settling may be obtained by reference to Table 4.

Since electrostatic precipitators are most effective for particle sizes below 5 microns (although this is by no means to be regarded as an upper limit), the usual test procedures for filters are not reliable when applied to this type of equipment. "Synthetic" dusts have been used, but it is customary to test electrostatic precipitators against outdoor air. Weight methods are ruled out since it is difficult to secure sufficient samples for weighing. In its place a discoloration technique is employed, consisting of filter-paper discs inserted in suitable sampling apparatus located on the upstream and downstream sides of the precipitator. The paper is discolored by the dust, and the degree of discoloration is determined by reflecting a constant source of light from each disc and measuring its intensity with a photoelectric cell. Direct comparison is also possible by decreasing the area of the disc on the downstream side while maintaining the same airflow through the sampling device as that passed through the upstream sample disc. The discs may be compared from time to time until the discoloration on both match. This requires a trial and error procedure since the area of the downstream disc often must be increased or decreased. However, if as is often the case, it is merely necessary to establish whether the efficiency of the collecting unit is greater or less than a stipulated amount, the ratio of areas is easily determined.

TABLE 4.—RATE OF FALL IN AIR OF PARTICLES OF VARIOUS DIAMETERS ACCORDING TO STOKES' LAW (SPECIFIC GRAVITY = 1.00)

Radius of Particle (Microns)	Rate of Fall
10	4320 meters per hour
1.0	43.2 meters per hour
0.1	43.2 cm per hour
0.01	4.32 mm per hour

Two questions are pertinent with reference to the discoloration technique: (a) Whether the efficiency of the filter discs can be regarded as constant for dusts collected on either side of the unit, and (b) whether the color properties of the dusts sampled are the same. These are critical questions which can be answered completely only by further research. It would seem, in the first case, that over a given period of sampling relatively fewer fine particles would pass through the upstream than through the downstream disc. This is purely inferential, and should affect the final result by making the efficiency lower than it should be. The second question is more difficult, but it is obvious that color is a function of particle surface (even for a homogeneous dust) and hence of particle size. In view of this, it is difficult to imagine how discoloration can yield reliable or even consistent results. It may be said that the future of air-cleaning will depend more on the soundness of sampling devices than on equipment design. If efficiency means the extent to which particulate matter is removed, then whatever the sampling device employed, its characteristics must be determined in terms of absolute particle count and size distribution. Nor must we overlook the fact that the haphazard method of drawing samples from a moving airsteam, as done at present, leaves much to be desired.

Bacteria Control Equipment

Both filters and electrostatic precipitators remove a certain amount of bacteria, the latter being quite effective. In these instances, elimination is achieved within the air supply system. Once the air enters any occupied space, all control by such equipment ceases. Air-borne bacteria are associated with occupancy, and are spread by sneezing and coughing. Unless such bacteria are reduced in numbers or destroyed by some means, the chances for a disease-infected person to infect others nearby may be quite great, especially where there is any degree of crowding. Therefore, we must consider ways and means of introducing some bactericidal agent, without simultaneously affecting individuals. We cannot eliminate all bacteria produced, even by a simple infected occupant of a given room, but if we assume that any depletion in the concentration of air-borne bacteria proportionately reduces the chances of infection in any person entering this same room we have accomplished a great deal. Since our present state of knowledge regarding air-borne infections is quite limited, we should not consider bactericidal agents or equipment as designed to eliminate *all* bacteria, but rather for reducing the possible chances of infection.

Ultraviolet Irradiation. It has long been known that ultraviolet radiation in the region of the spectrum below 3000 Angstrom units, especially around 2600 Angstrom units, is effective in destroying microorganisms. The early investigations by Wells,

and since then by many others, have fully demonstrated that low pressure mercury lamps with glass or quartz envelopes can be used to reduce the air-borne bacteria population of occupied spaces. These lamps emit almost 80% of their radiation at a wave-length of approximately 2600 Angstrom units. We have already mentioned results of some of Wells' investigations. We shall now dwell more fully upon the methods of applying ultraviolet radiating sources. There are three methods used for controlling air-borne bacteria: (1) by irradiating the upper air stratum of a room; (2) by beaming or screening; and (3) by insertion in an air plenum or duct. The last-mentioned method has been discussed, and possesses merit in that the source of radiation is concealed. However, as we subsequently pointed out, air-borne bacteria control depends on their destruction within the occupied space itself, so that this method is effective only for rendering an air supply that is practically bacteria-free.

Irradiation of the upper air stratum, usually the upper third, is done by placing lamps within an upwardly directed reflector. This method depends for its effectiveness upon natural or forced air circulation in the room. How much is accomplished by reflection and scattering is not known, but it is obvious that the technique is best suited to rooms with high ceilings. There appear to be no published data relative to number or distribution of ultraviolet lamps within a given room, nor are occupancy and bacterial relationships available. The success of this method of air-borne bacteria control is based on practical experience and established knowledge that the concentration of organisms is definitely reduced.

The second method, which consists in beaming a narrow strip of radiation across a given area, is employed as a barrier or screen to prevent cross-infections in hospitals, and to protect tellers and others who have constant contact with the public. The beam method is best suited to relatively narrow areas. Otherwise, to be effective, a strong intensity of radiation must be used, possibly resulting in some danger to persons passing through such a beam. Since exposure time is quite important in destroying bacteria, it is obvious that this is a limitation of the beam method, although its success in reducing hospital cross-infections has been demonstrated.

Whichever method of applying ultraviolet radiation is used, it is necessary to observe certain precautions. Radiations of the order of 2600 Angstrom units are dangerous to the eyes and skin of occupants, so ultraviolet lamps must not be located within the range of vision. Effects of exposure are so severe that the Council on Physical Therapy of the American Medical Association in accepting ultraviolet lamps for disinfecting purposes, states that "the manufacturer and distributor of such lamps must assume some responsibility for the adequacy of the lamp installation for the purposes of radiant disinfection of the air, and for the *adequacy of the protection from injury of the occupants of the space irradiated.*" (Author's italics.)

A vast amount of work remains to be done with regard to ultraviolet installations. There is ample evidence of their success, especially in hospitals where infections have been reduced radically, but there is certainly room for improvement particularly as to protection of occupants from direct and indirect radiation, as well as with regard to the all-important problems of lamp distribution and energy requirements. The effects of humidity and dust are also important and require investigation.

Chemical Bactericides. During the past three years great impetus has been given to the use of certain chemical agents, particularly the glycols, as bactericides. These substances may be introduced into the air in very low concentrations and are efficient against almost all types of air-borne bacteria. Whether their action is chemical or physical has not been determined.

Of the various glycols which have been studied, propylene glycol seems to be most effective. It has been found that the action of this substance is instantaneous, but best results are obtained when the concentration of air-borne bacteria is small. The most favorable conditions for lethal action take place at temperatures below 80 deg F and relative humidities within the range from 45 to 70%.

Propylene glycol mist has been found to destroy partially and completely dehydrated bacteria, but non-sterile dust collected from inhabited rooms, after being dispersed into the air which was then treated with the bactericide, showed only a small reduction in the original bacteria content. This effect also pertains to ultraviolet radiation and indicates the need for dust removal as an adjunct to bacteria control.

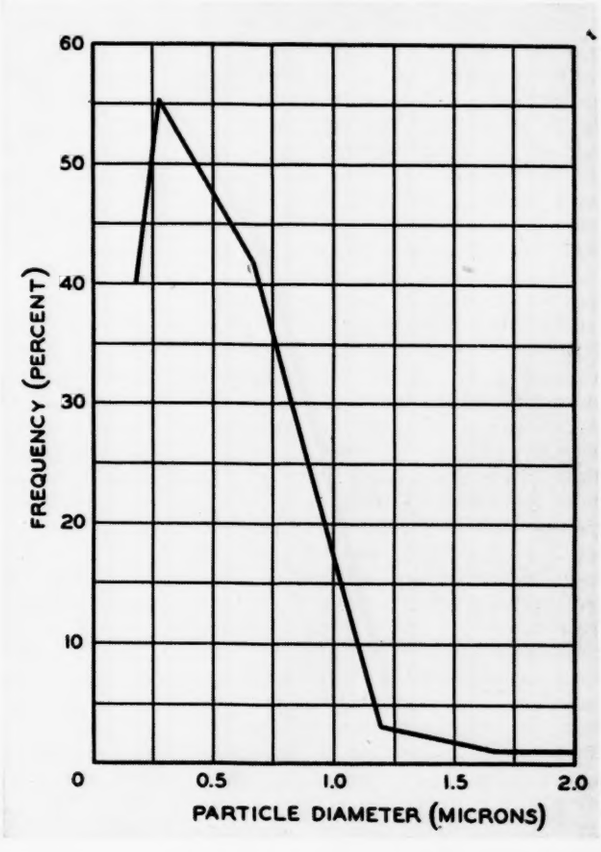

Fig. 5. Particle-size distributions of outdoor dust.

As to the concentrations of propylene glycol required, these are surprisingly small. Pneumococci are killed with amounts as low as 1 gram in 20 million cubic centimeters of air, and 1 gram in 5 to 10 million cubic centimeters are effective against streptococci and staphylococci. These concentrations are both non-toxic and odorless to human beings.

No commercial method for introducing the above bactericide is available at present, but there should be no difficulty in designing suitable equipment. The use of chemical bactericides, of course, has several advantages over ultraviolet light, such as location of necessary equipment in the air plenum or duct and hence its elimination in occupied spaces, and the certainty that all air in mechanically ventilated buildings is effectively treated. All this is predicated on the assumption that propylene glycol or any other suitable bactericide proves to be as useful as present information indicates.

Bacterial Efficiency

Determination of the effectiveness of a given filter or other apparatus for removing air-borne bacteria has never been accomplished satisfactorily. Both Wells and the writer at various times have attempted to set up suitable procedures, but it seems that until more is known regarding the kinds of bacteria we are most concerned with, no one can be certain in stating precisely the absolute degree to which bacteria have been removed. The real facts of the matter are that we do not know what bacteria or viruses are air-borne, nor are we thoroughly familiar with the methods to be used in sampling and culturing them. Wells originally suggested the use of *E. coli*, a common gastro-intestinal organism. Later, from his extensive researches he was led to use a naso-pharyngeal type which is an index of many common respiratory ailments.

Although knowledge pertaining to air-borne bacteria remains in a state of flux, too much emphasis should not be placed on the lack of suitable yardsticks for measuring effectiveness of bacteria-removing devices. As long as there is any index available, however imperfect, we may determine the degree of removal effected. When more is learned of the kinds of bacteria to be concerned about, whether by direct bacteriological examination or by indirect epidemiological studies, we shall better be able to devise competent tests for determination of efficiency. But, as Wells pointed out, for the time being control of air-borne bacteria is a firmly established necessity, and its progress should not be withheld simply because its effectiveness cannot be measured accurately.

Before closing our discussion of bacterial efficiencies, mention should be made of the standardization of certain bactericidal agents. Wells established the unit *lethe* for ultraviolet radiation, and it is probable that a similar unit can be established for some of the chemical bactericides now under development. This is indeed valuable although in practical installations it often becomes necessary to have actual performance data available. In general the status of bacteria removal efficiency is about identical with that of dust collection, but the future may show possibilities of advancing to a greater degree of perfection and even indicate the procedure to be followed for evaluating dust collecting efficiency.

Methods for Controlling the Odor

Thus far there seems to be only one method of controlling odors, namely by adsorption with activated charcoal. This substance is effective against body, cooking, tobacco, and other odors normally associated with occupied spaces. The charcoal may be reactivated after it has become saturated, but there is no method for determining this condition other than the re-existence of odors it is intended to adsorb.

Activated charcoal adsorbers can be used only with mechanical ventilation and should be protected by dust control apparatus. They are generally used to improve recirculated air and reduce the cost of conditioning fresh air. It is claimed that dust does not affect adsorbers and that they are efficient in destroying bacteria.

It is not the purpose of this article to discuss the various properties of activated carbons. These are highly technical. The precise action which takes place and leads to adsorption of vapors and gases is not well understood, but is probably a surface phenomenon. The degree of adsorption depends in part upon the partial pressure of the vapor or gas as well as to their molecular weights and chemical properties.

The exact role of odor adsorbers in ventilating systems must be considered one of pure economics. Certain conditions may exist when it is necessary to remove odors contained in outdoor air, but by and large odor adsorbers are used to permit a higher degree of recirculation, thus reducing the cost of cooling or heating fresh air. Otherwise, odor problems can be handled easily by dilution methods. It is interesting to point out that recent investigations on ventilation of occupied spaces by Yaglou and others tend to show that if odors are used as criteria for ventilation needs the amounts of fresh air required are far in excess of those formerly used by designing engineers. Room size and occupant density were shown to be important variables not considered heretofore.

Odor Removal Efficiency. Since the odor scale is logarithmic, the expression for efficiency as used in dust and bacteria removal does not hold. In this case it is necessary to think in terms of "reduction," as in the case of noise elimination. Unfortunately, there has never been any general agreement as to the odor scale itself, so until this has been done any reduction, say from an odor intensity of 5 to one of 3, is quite meaningless without first specifying the scale of the subjective sensations we are recording.

Measurement of odor reduction cannot be done satisfactorily by one person, or even by two or three, although properly trained. There is no uniform degree of odor sensitivity among individuals, and we must resort to the preponderance of sensations recorded by as many persons as possible. No reliance can be placed on reactions classed as "definite" or "moderate" since mere definition of these terms cannot evaluate a sensation. A more quantitative procedure is indicated, and this will be outlined below.

Since the only important distinction is whether an odor is or is not detected, we have merely to proceed as follows: Using a two-compartment test chamber (one compartment of which is to be fed with odor-free air, and the other to be piped with air from any odor source), arrange the latter so that any measured amount of odor-free air may be added. The experimenter is stationed in the odor-free compartment, and either by means of an odoscope or by passing through suitable connecting doors to the odor chamber, adjusts the fresh air supply to the latter until no odor can be detected. The ratio of volume of odor-free air to

the volume of air supplied from the odor source may be used as an index of intensity. Indices so derived will vary with different odors, but the chance of arriving at purely quantitative results is better than that used at the present time. Moreover, it reduces the subjective aspect to a minimum, and reliable results should be obtainable by a single observer. A schematic drawing of the arrangement of the test chamber is shown in Fig. 6.

Economics and Future of Air Sanitation

There can be no question but that the sale of air sanitation equipment will become as important as the sale of heating and cooling equipment. Certainly there is a large potential market at present, since the need for air sanitation equipment is not limited but rather is quite universal. The market for unit-type apparatus for houses and apartments is very great but for some reason it has so far escaped the attention of manufacturers. However, it would be unfortunate if development of the air sanitation market were done indiscriminately. The public, and also the designing engineer, should be better informed about the purposes and limitations of equipment now available. Some of these were discussed in the foregoing, and will be emphasized again below. At this point we shall attempt to gauge the economics involved.

It was stated earlier that the mere existence of air sanitation equipment is one of simple economics. This was reiterated in various places, while at the same time we covered the direct and indirect benefits. For dust and odor control equipment the dollars-and-cents savings may be evaluated in many instances. Thus far, except in the case of industrial dusts, it has not been possible to show that ordinary outdoor dust and odors are inimical to human beings. They may be nuisances and inconveniences, but fundamentally when equipment for their control is installed it is for purposes of making a more efficient working environment, reducing time lost in cleaning desks, papers, etc., and in preserving materials and goods. This may not be so obvious with bacteria control, yet every employer—as well as those directly affected—knows the cost of absenteeism due to common diseases. We may be relatively certain that when bacteria control equipment is installed in any large building, it is for the primary purpose of cutting down such costs, although in the end the public health will benefit.

The present cost of dust removal equipment installed ranges from ½ to almost 50 cents per cu ft per min, depending upon the type of equipment installed. Maintenance charges on the more expensive units such as electrostatic precipitators are low, but on the cheaper units of the throwaway type (that is, those discarded when dirty) may run as high as ten times the initial cost.

These are costs for dust removal equipment only. If we add the equipment costs for bacteria and odor control, the total becomes impressive. It is clear that we are faced with determining when and to what extent air sanitation is indicated in a given instance.

At the present time most purchasers of air sanitation equipment have no way of knowing exactly what is to be desired, unless the problems are related to production angles. Generally, the desideratum in ventilation work is equipment to accomplish a certain degree of control at minimum cost. The amount of control is judged either *a priori* in terms of standardized tests, or by guarantee that in actual operation a specified amount of control (usually expressed as efficiency) will be attained. However, the purchaser rarely knows what is needed, and little information is available to him regarding a standard of good air sanitation to be achieved. We have stressed the many-sided aspects of the term "efficiency" as commonly employed, and in so far as its competency in comparing one type of unit with another is concerned no criticism can be levelled against such practice. But in a final analysis should there not be something in the way of a "clean air" standard?

A standard of clean air is the only one which can convey to purchaser or designer the precise accomplishments to be required of any piece of equipment. It is not too late to begin studies or develop discussion of this matter. The potential market is very large, and it would be unfortunate if the public had nothing but the inadequate term "efficiency" to coax it into a sense of security. It is not necessary to remove everything present in the air. From an immunological standpoint this may be highly undesirable. But there must be some absolute basis for establishing the degree of air cleanliness desirable. Without such a standard there can be no progress in air sanitation.

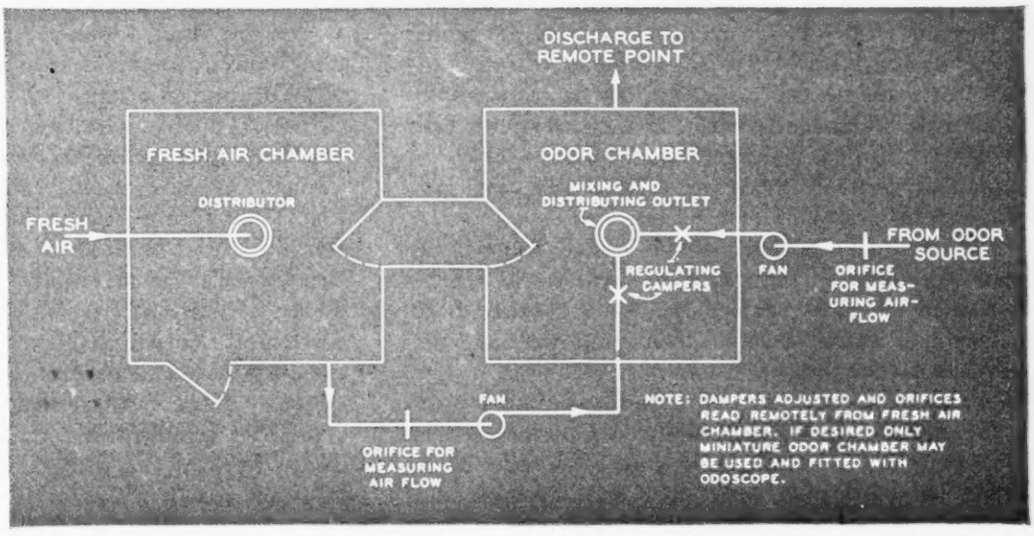
DISCHARGE TO REMOTE POINT
FRESH AIR CHAMBER
ODOR CHAMBER
DISTRIBUTOR
MIXING AND DISTRIBUTING OUTLET
FRESH AIR
FROM ODOR SOURCE
REGULATING DAMPERS
FAN
ORIFICE FOR MEASURING AIR-FLOW
FAN
ORIFICE FOR MEASURING AIR FLOW
NOTE: DAMPERS ADJUSTED AND ORIFICES READ REMOTELY FROM FRESH AIR CHAMBER. IF DESIRED ONLY MINIATURE ODOR CHAMBER MAY BE USED AND FITTED WITH ODOSCOPE.

Fig. 6 Arrangement of odor-test chamber for determining degree of odor intensity.

Studies of Exposure to Dust and Fumes

Studies on exposures to arsenic dust, lead dust and fumes, free silica, synthetic resin dust and other substances were made during the past year by Industrial Hygiene Foundation. In a paper by Dr. F. R. Holden and W. C. L. Hemeon, before a meeting of the Industrial Hygiene Foundation, Pittsburgh, Pa., some of these studies were described.

The problem of determination of the free silica content of air-borne dust recurs frequently in the foundation's work. It is an established fact that the dust thrown into the air seldom has the same free silica content as the parent material from which the dust originated. While there are several methods for determining the composition of such dusts, mainly the X-ray diffraction analysis is used for that purpose. Both chemical and petrographic methods have given unreliable results at times. For example, an air-borne dust containing clay with a known quartz content of 35% was found to have only 2% free silica by the petrographic method.

An experience in one plant points up the importance of checking the weights of cylinders of liquefied gases upon receipt. In the present case a cylinder, which was liquid-full exploded, endangering the lives of nearby workmen. Investigation disclosed that the cylinder contained 18 lb more gas than permitted by law. When toxic gases are being used, no cylinder should be accepted which is leaking or which contains more chemical than is allowed by I.C.C.

A new addition to the occupational disease jargon, "angel eyes," derives its name from the corona effect observed when the workmen look at a light at night after excessive exposure to hypochlorite dust. The effect is caused by a slight edema of the cornea, the fluid acting as a prism.

One result of the war has been to greatly accelerate the production of silica gel, since that chemical is important as a hygroscopic agent and as a catalyst. The institute has had occasion to appraise health hazards in a plant manufacturing quantities of this material. It is curious that silica gel which is a hydrated form of free silica has shown no tendency to cause silicosis when applied experimentally to animals. Gardner's work, in fact, indicates that its effect is similar to that of inert dusts. Data on human exposure to silica gel, it is hoped, will confirm the results of animal exposure.

The authors reported, "the fluoride problem has been encountered in much of our field work. In no case that we have studied has the exposure been sufficient to cause skeletal effects, but we have observed both skin irritation and nose bleeding.

"Tests were conducted in a railroad tunnel prior to the undertaking of some repair work which would keep a number of workmen engaged for some days. Trains passed through the tunnel on an average once every 15 minutes throughout 24 hours of the day. Although the tunnel was ventilated, it was important to determine definitely whether concentrations of carbon monoxide or sulfur dioxide would reach a point where they would endanger the workmen or interfere with the project. It was found that carbon monoxide did not exceed 50 parts per million at any time, which is entirely safe for a complete working day. But concentrations of sulfur dioxide were in excess of acceptable concentrations and definitely objectionable. Accordingly, the workmen were supplied with chemical cartridge respirators for protection during the few days required for the job.

"Methods of microanalysis of air used in industrial hygiene work are often usefully applied to other plant problems. One such application concerned extensive and serious corrosion of machine and metal products, the cause of which was unknown. With the aid of techniques applied to our more usual problems it was finally proven to be caused by hydrogen chloride from trichlorethylene degreasers. The trichlorethylene was of a poorly stabilized grade which decomposed, releasing acid gas into the shop. It was possible to correct the condition by adopting a better stabilized solvent. Thousands of dollars in cleaning bills were saved by eliminating the cause of the corrosion.

"Problems in general air pollution have occupied considerable attention in our field studies during the year. Sulfur dioxide, a potential killer of some vegetation when present in sufficient concentrations, and other chemicals, obnoxious in nature, have been the subject of some investigations. We anticipate that community air pollution by industrial dusts will receive wide attention after the war.

"In one of our studies for measurements of the degree of contamination of a neighborhood by sulfur dioxide, we were able to indicate a remedy. It involved metering and controlled dilutions of the gas which would reduce its consumption to 5-10%. This, obviously, would improve atmospheric conditions within the plant, widen the margin of safety outside, and simultaneously show a profit.

"Widespread interest has appeared in abatement of nuisance of fumes from electric furnaces. There are three practical methods available for the control of such fumes, each with advantages and disadvantages: (1) Canopy hoods, which are usually not applicable to the furnaces of smaller capacity or where the craneway is materially greater than 25-30 feet above the furnace. (2) A sufficiently large volume of general ventilation by means of propeller fans in monitors is also effective. (3) Application of local exhaust is the most desirable method wherein the fumes are removed at their source—the base of the electrodes and the firing door. This is by far the most efficient method of all since it requires very much less air flow than either of the other two."

Health Hazards Associated with Welding

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AS with any other engineering process, the health hazards associated with welding can only be evaluated with respect to a particular time. In some measure the same hazards are, of course, always present, but as time goes on and new methods, new materials and new equipments become available the need ever repeats itself for a re-evaluation of the extent of known hazards and a search for other and unknown hazards. Changing methods remove old dangers and produce new ones, while some dangers continue uninterruptedly.

If medical case histories were available for the important characters of literary history we would be greatly interested in knowing whether one of history's first recorded welders—Vulcan—ever developed nodular mottling as a result of inhaling the fumes which made it necessary for him, as Homer tells us in Book XVIII of the Iliad, to sponge away external deposits from his "sturdy neck and shaggy breast." We would ask, too, whether Vulcan became a recluse as a result of the "nervous irritability" which is noted by Kny as an effect not infrequent among welders. Likewise we would like to know whether he suffered from giddiness—particularly after a vertical change in position—or was troubled by falling hair, nausea, loss of sex potency, spasms, or gastric pains. Perhaps we could also use the case history of this Greek god as evidence in an attempt to settle the controversy between the one group of modern investigators who are of the opinion that welding may be a responsible factor in an increased incidence to common colds, and the other group—equally as vehement—who suggest welding as an occupation which may relieve those who have a susceptibility to the common cold.

The literature on welding hazards is replete with paradoxes and with contradictions. Many investigators report that nitrous oxide is a real and, under certain conditions, serious hazard, while one man, in contradiction, says that nitrous oxide cannot and does not exist outside of the arc. Some report that significant systemic effects may be noted as a result of exposure to radiant energy from the arc; others report that no such systemic effects have yet been adequately demonstrated. In view of this seemingly confused state of the literature a brief review, based on currently accepted opinion and with health hazards re-evaluated in terms of present conditions, may be of interest and value to the engineer. For detailed and documented reports on particular hazards and their method of control the reader is referred to the original publications in the fields of hygiene and medicine where these subjects are given full attention.

Classification of Hazards

Aside from indirect occupational hazards, or obvious direct hazards such as that of being burned, the specific dangers to health which are of importance in welding originate from three basic causes:—irradiation of the occupant from the arc as a radiant energy source; toxic gases formed in or around the arc; fumes produced during the welding process. Each of these three general classifications of hazard can be sub-divided to give more accurately the nature of each particular danger as a function of the conditions which exist on a specific welding job. The three major classifications are by no means independent of one another. The quality of radiant energy emitted from the source varies as function of temperature, but so also does the effectiveness of the arc as a producer of both gases and fumes. Thus a change in arc temperature from its average value (around 5000F) may readily alter the quantity and quality of the irradiation received by the worker, the quantity and the kind of toxic gases produced, the quantity of fumes and the size of fume particle.

Irradiation

The consensus of present opinion seems to be that known irradiation hazards are limited to the skin and to the eyes. The lens of the eye has a very low thermal diffusivity and is therefore especially subject to damage as a result of inability to rapidly lose the heat produced therein due to absorption or radiation. Actinic conjunctivitis ("arc flash") is not uncommon and is characterized by a delayed onset accompanied by a slow swelling of the lids and a "scraping" feeling as of sand in the eye; its normal course is approximately twenty-four hours.

Some indication of the amount of irradiation received from the arc is manifested in the fact that an electric arc emits over one hundred times as much ultraviolet radiation as does an acetylene flame and nearly one hundred-fifty times as much as a carbon arc. The minimum safe distance from the arc (for an unprotected eye) is estimated at 200 feet; thus need exists not merely to secure protection of a welder from his own work, but also from that of even distant neighbors.

The effect of high intensity radiation in the visual

region on dark adaptation of the eye has been investigated by Kuhn and Wille who find no evidence to substantiate the complaints of welders that a lack of such adaptability is a consequence of the occupation; further, their findings give no evidence of a decrease in the ability to achieve dark adaptation after working for an eight-hour shift.

The effect of irradiation by energy in the infra-red is essentially that due to secondary heat production, but Pozzi calls attention to certain cases in which cataracts have formed as a result of prolonged exposure to such radiation. Contrary to popular opinion, there is no evidence of radiation from arc welding (according to Le Compte) which is hazardous to the genital organs.

Fumes

Under the heading of "fumes" will be considered hazards resulting from exposure to smokes, fumes, dust, or any other particulate material as distinct from the gases, as ozone and the oxides of nitrogen, which will be discussed in a separate section. Fumes may arise during the welding process from the rod, rod coating, material being worked, or surfacing—as paint—on the material being worked. In general, welding fumes consist of particles smaller than one micron (1/25,000 in.), but particles up to 8 microns are not uncommon.

Particulate fumes of iron are dissipated as an iron oxide fog consequent upon the "boiling" of iron at arc temperature; average particle size is less than 5 microns. Koelsh found deposits of iron in the lungs of 18 out of 40 welders who were examined; the dust was approximately 97% iron oxide and three of the individuals examined showed lung changes not unlike the kind that are observed in cases of silicosis. In general such changes seem to be evidenced as a nodular mottling observed after exposures of fifteen or more years to the products of arc welding. Since 1936 several reports of such pulmonary changes attributable to the occupation of welding have appeared in the literature. However, a distinct difference exists between lung changes due to iron oxide fumes and the somewhat similar changes which occur as a result of prolonged exposure to high concentrations of silica:—the connective tissue absorbs the iron oxide and no fibrosis, of the type found in silicosis, occurs.

Zinc oxide fumes, resulting from the welding of galvanized iron, are responsible for metal fume fever and should therefore be guarded against. This material is not cumulative, however, and there is evidence to indicate that it does not predispose to tuberculosis. Welding of painted iron affords an obvious risk of lead poisoning.

Many other kinds of fume hazards exist in welding. Electrodes of manganese, chromium, aluminum, nickel, zinc, and magnesium may be used and coating fumes may include fluorides, silica, silicates, bitumen, varnish, and rubber. Kny reports liver injury as possibly attributable to long exposure to metal fumes while Haam and Groom consider the toxic effect of fumes and dusts more serious in welding than the toxicity of gases. The latter investigators report, however, that there is no satisfactory evidence of the causation of gastro-intestinal disturbances, nervousness, or sex troubles as due to the inhalation of metal fumes; they find that the only observed effect of exposure to such fumes is in the changes which occur in the upper respiratory tract. The effect of manganese fumes is particularly subject to question. Some investigators suggest such fumes as the factor responsible for sexual impotence of welders, but this point is by no means settled as certain investigators have found impotence as a frequent complaint among welders while others state that there are fewer cases among welders than among any other group of industrial workers.

The extent of the hazard due to fumes obviously increases as working conditions become more crowded and welding processes find more extensive application. In shipyards, at the present time, it has been estimated that no less than one-half of the workers are exposed to concentrations of fumes which, at least legally, could be considered hazardous. By adopting adequate methods of control the fume concentration can be reduced to a value such that no hazard to breathing will exist, but such control will in most cases require careful work planning and—in many instances—the installation of special equipments or exhaust systems.

Some indication of the extent and nature of the fume hazard is noted from a study of the Krupp steel works, made under wartime operating conditions, which showed that 16% of the electro-welders (out of 410 examined) had suffered from severe gastro-intestinal troubles while an additional 22% were bothered slightly by disturbances of the same sort. In this investigation it was found that the time of onset varied from a few weeks to many years and that absenteeism (due to digestive disturbance) among electro-welders was three to five times as great as for any other group of employees.

Gases

Carbon Monoxide. A large proportion of the fatal accidents which have occurred in welding have been traced back to the inhalation of toxic gases produced in the arc or liberated as a result of the welding process. In one case involving the death of seven oxy-acetylene welders autopsy showed nitrous vapors as the cause of the poisoning. The presence of traces of carbon monoxide with nitrous gases seemingly serves to activate the poisoning while traces of nitrous gases, in an atmosphere with a hazardous CO concentration, serve to increase the sensitivity of the body to monoxide poisoning. Carbon monoxide is produced in the arc as a result of dissociation of carbon dioxide (at arc temperature), but when sufficient oxygen is available recombination occurs during cooling and there is no likelihood of a noxious CO concentration at the breathing level.

Under normal conditions carbon monoxide in welding is only a minor hazard, but when work is done in confined or small unventilated spaces the consumption of oxygen may lead to an oxygen deficient atmosphere in which a hazardous carbon monoxide concentration can exist.

Ozone. At the high temperature existing in the arc, ozone is said to be formed due to absorption by oxygen of ultra-violet radiation. However, disintegration and dilution both occur rapidly following departure from the arc zone so the health hazard represented by this gas is usually not serious. Harrold and co-workers report that concentrations of from 10 to 32 ppm are found 1 in. from the arc, 1.5 to 9 ppm at 4 in. from the arc and between .2 and 1 ppm at a distance of five feet; their tests were conducted in a 1000 cubic foot enclosure. Coltman and Macpherson report that they could not find (based on spectroscopic tests) any trace of ozone in a typical carbon arc.

Physiologically, ozone is irritating in concentrations as low as 1 to 2 ppm; that is, in concentrations corresponding to a level at which its odor is first noticed. Present opinion tends toward the belief that no appreciable ozone hazard will exist if adequate control is provided for the more serious fume and nitrous gas hazards.

An additional arc hazard resulting from artificial ionization has been recently reported. According to Dr. Kiper this may be responsible for changes in metabolism, blood pressure, pulse and respiration. The literature on the extent and severity of the ionization hazard is so meagre as to preclude any present conclusion.

Nitrous Gases. Of the various oxides of nitrogen, nitrous oxide (N_2O) is the only one which is non-irritating. Its use as an anaesthetic ("laughing gas") is well known. Titric oxide (NO) is a colorless gas and is the most stable of the group, but it readily oxidizes to form reddish-brown (when hot) nitrogen tetroxide (NO_2) which, on cooling, becomes pale yellow and is chemically identified as (N_2O_4); nitrogen tetroxide is the most irritant gas of the nitrous group. Other nitrous gases are the trioxide (N_2O_3) and pentoxide (N_2O_5).

Monoxide of nitrogen is thirty times as poisonous as carbon monoxide and is said by many investigators (as Britton and Walsh) to be the most significant nitrous gas found in the arc and in all kinds of welding. At a temperature of 3600F approximately a 1% fixation of atmospheric nitrogen occurs (giving NO as a product) while at 5400F fixation of 5% of the mixture can take place.

Nitrogen peroxide formed on striking an arc will produce a fatal edema if ventilation is poor and the concentration at the breathing level is allowed to become sufficiently high; lower concentrations, while not fatal, may be severely irritating. Nitrous gases, in general, have been found to be seriously irritating when present in concentrations above 30 ppm. Leschke indicates that fatal results can be expected after 5 to 10 minutes exposure in a concentration of 500 ppm; for 100 ppm an exposure of 30 to 60 minutes is dangerous while 50 ppm can be endured for one hour. The characteristic effect of poisoning from nitrous gases is lung edema following a latent period which continues for some hours subsequent to the actual period of exposure. Harrold, Meek,, and McCord give the harmful concentration of nitrous gases, for prolonged exposure, as in excess of 70 ppm and they were unable to produce any physiological effects from the concentrations of such gases realized in carrying out experimental work with a given type of welding procedure. Possibly the differences in threshold concentrations, as found in the current literature, are due to variation in the distribution of constituents which make up the ambiguously labelled "nitrous" gases. Lacking further data, however, it would seem that the engineer would be reasonably conservative if he designed a control system which would assure maintaining the breathing level concentration of nitrous gases at less than 50 ppm.

Nitrogen tetroxide (NO_2) is said by Tollman and co-workers to be sufficiently hazardous as to lead to death if breathed in concentrations greater than 100 ppm for four hours a day over a prolonged period. The upper safe limit for this gas is said by other investigators to be 39 ppm and it is further stated that concentrations in excess of this are unlikely to occur under normal working conditions. An experimental investigation of the distribution of NO_2 resulting from a typical welding process showed 30-70 ppm within 3 in. of the arc, but less than 2 ppm at 18 in. Reduction in the concentration of this gas also accompanies the use of coated electrodes; the amount of NO_2 produced when using coated steel is only 30 to 50% as much as when bare steel is used. Drinker states that no hazardous NO_2 concentration can occur in a large shop room in which a minimum natural ventilation rate of 1-3 air changes per hour exists. In any event the concentration of nitrogen tetroxide is always small in comparison to the fume concentration and therefore any consequent hazard will be automatically safeguarded against as a result of application of suitable measures to the problem of fume control.

Criteria of Control

Recognizing the possibility that hazardous conditions may result from many kinds of fumes and gases produced or liberated during the welding process, the problem of preventing such health hazards becomes one of finding means of limiting the concentration of toxic materials, at the breathing level, to a safe value. This objective can be realized in many ways. Isolation of the welding process from the main shop structure (as by use of small isolated rooms), or isolation of the welder's respiratory system from the general atmosphere (as by a mask or respirator) represent two extremes of treatment. More common methods are those of reducing the concentration of toxic material by bringing into the

working space the requisite volume of ventilation air (dilution) or extracting from the working space the requisite quantity of toxic materials (exhaust systems).

Regardless of the method used, the fundamental criterion of effectiveness is the resultant concentration of toxic materials. Thus the necessary starting point in any engineering study of fume, dust, and gas control is a knowledge of the permissible safe level. This varies greatly. Evidence suggests that air-borne fluorides in concentrations greater than 5 milligrams per cubic meter may, for prolonged exposure, lead to serious effects. Concentrations of 20 mg per cu. in. of zinc oxide can be responsible for metal fume fever. Nitrous gases are irritating in concentrations exceeding 30 ppm and ozone concentrations over 1 ppm may be objectionable.

The problem thus requires simplification and what is needed is the value of an overall total fume concentration which, for average welding operations as conducted under usual present-day operating conditions, will assure reduction of all hazardous constituents in the total discharge from the arc region to individual concentrations each of which is below the hazard threshold for its particular material. The use of such an overall criterion is obviously suspect as there is always the possibility that special conditions will occur on a particular job which will invalidate the empirical relationship between an individual constituent and the total quantity of fumes. Thus experience indicates that a hazardous fluoride concentration (5-8 mg per cu. in.) is not usually found in welding fumes until the total fume concentration has risen to a value in excess of 25 mg per cu. in. From this empirical relationship it seems safe to use 25 mg per cu. in. as an overall criterion, but in doing so recognition must be accorded to the possibility that under special conditions this relationship may break down and hazardous fluoride concentrations are conceivable in conjunction with overall fume concentrations much less than this value. The use of such overall criteria must always, therefore, be tempered with caution based on a comparison of conditions for the actual installation with the "average" conditions for which the empirical relationship was originally established.

Based on research by many investigators present experience indicates that if the total fume concentration is kept below 25-30 mg per cu. in. there will be little possibility of reaching a hazardous concentration of nitrous gas, ozone, fluorides, zinc oxide or any other toxic material resulting from a welding process. In many cases this criterion is substantially over-conservative since for certain types of work no toxicologic justification exists for limiting the fume concentration to such a relatively low value. However, considerations of comfort and the need for maintaining reasonably good visibility in shop spaces is usually considered adequate reason for applying a 25-30 mg per cu. in. limit even where control of a health hazard does not require it. In large rooms where wall-to-wall visibility is needed (as for safe crane operation) the concentration must be reduced to less than 15 mg per cu. in. Thus it is evident that visibility is itself a moderately effective means of estimating the extent of the health hazard; if visibility is not seriously impaired the hazard can be considered non-existent, while if pronounced reduction exists the probability of a health hazard is rather high.

Methods of Control

The two fundamental methods used in reducing fume concentration—"dilution" and "exhaust"—are very dissimilar. The primary factor contributing to the success of a dilution system is the *volume* of air admitted; in an exhaust system volume is important only insofar as it may be necessary to the realization of air *velocity*. In a dilution system the quantity of dust and fume is fixed and the need is therefore to provide a volume of air adequate to reduce the concentration below the specified limit. In an exhaust installation, the volume of contaminated work room air is fixed and the problem is one of extracting a weight of particulate matter such that the remaining solid material will not unduly raise the concentration. The sole function of the air withdrawn in an exhaust system is to act as a vehicle for conveying the solid matter; the more effectively the air can be "loaded" with dust and fumes the smaller will be its requisite volume. This distinction between *volume* in dilution and *velocity* in exhaust is an obvious one once the purpose of each system is fully realized but misconceptions continue to occur so frequently as to justify this reminder.

Design of a system for use in dilution requires some knowledge of the weight rate at which fumes are produced. Based on extensive experimental work Drinker and Tebbens recommend a minimum ventilation rate of 250 cubic feet per minute per welder when using coated rods in a space of volume less than 2000 cubic feet. With rod sizes over 5/32 in. this minimum rate should be increased approximately as the square of the rod diameter. For larger spaces the natural ventilation rate can be determined by usual methods and will ordinarily be found more than adequate in providing the indicated necessary minimum air volume.

Design of a system for use in control by exhaust requires some knowledge of the air velocity at which fumes are trapped. The basic requirement of any such system is that it provide—at the point of fume origin—a directed velocity sufficient in magnitude to prevent escape or dispersion of the particles. With reasonable allowances for a safety factor recommended velocities vary from 100 fpm (5/32 in. rod or smaller) to 200 fpm for a 3/8 in. rod. Any type of hood, hose, or other air inlet which will provide this directed velocity throughout the region of fume origin will assure adequate protection from hazardous breathing level concentrations. Design of ex-

haust systems for this purpose should be based on aero-dynamic analysis of the hood arrangement and can be done by application of the theory of potential flow or by graphical construction from an experimentally determined simple flow field.

Conclusion

Health hazards associated with welding arise from the heat of the arc, radiation emitted by the arc, and from gases, fumes, and dust which are by-products of the welding process. The literature contains many references to systemic disorders attributed to welding but as yet there is no positive evidence that such effects represent a widespread hazard. Recognized danger does exist, however, in prolonged exposure to welding gases and fumes liberated in a confined space. To eliminate this hazard it is suggested that the control be provided to reduce the overall fume concentration below a limiting value of 30 milligrams per cubic meter. This can be done by dilution (controlled air volume) or by use of a local exhaust system (controlled air velocity in region of fume origin). No appreciable fume hazard will exist in any space where the concentration is so low as not to appreciably reduce visibility.

Aye, There's The Rub!

WHEN superintending construction work, it is always desirable, and sometimes necessary, to have a complete record of the make, type, serial number and characteristics of the various pieces of apparatus installed on the project, as well as mill stamps or inspectors' stamps on tanks, boiler plates, motors, and so on.

The usual custom is to copy these data into a notebook from the manufacturers' name plates on the various pieces of equipment. This method, however, quite frequently leaves a loophole for doubt to creep in, as there may have been an error of either commission or omission made in copying the data.

There is a better way, in that it will, if carefully followed, substantiate any data which may be copied. The writer used this scheme for several years, when supervising construction work and, in at least one instance, it saved a day's time and a round trip of some 400 miles, due to the fact that the record in the field notebook presented the desired information in a form of which the accuracy was beyond question.

The scheme consists wholly in having each piece of apparatus present the desired data, so to speak, over its own signature. This is accomplished quite readily, in one of at least two ways.

The first consists in holding a sheet of moderate weight paper (a leaf of the notebook, if possible) firmly in place over the plate or mark and rubbing over it with a lead pencil. The pencil must not be too soft—say about an H or HB. Raised letters record themselves readily, but care must be exercised in the case of sunken, or stamped in, letters or figures. Any which are not clear can be noted at the side of the rub, on the proper line, and with these as a guide, if the work has been carefully done, it will usually be possible to identify the figures on the reproduction. If a separate piece of paper has been used, it should be pasted in the notebook, as soon as possible, so that it will not be mislaid, or lost.

The second of the two methods mentioned gives a much more accurate and detailed impression, but one more easily defaced and, for that reason, more difficult to preserve. It cannot be safely pasted or carried in a notebook, as it must be protected from abrasion, deformation and pressure.

This method consists of the substitution of a piece of thin metal for the paper—say lead foil, such as used to be used for the wrapper of certain makes of smoking tobacco. In this case, instead of using the pencil point, the eraser is used and, with a little care, a very fine impression can be made. It must, however, be preserved by pasting it on a piece of cardboard with a "mat" of the same on the front and, preferably, a piece of cellophane over the opening of the mat, or other means of preventing its being subjected to pressure.

The writer has usually used the former of the two methods as being the more ready and practical; easier to preserve and usually just as satisfactory. He uses the metal foil only for "special occasions," where greater accuracy is actually necessary.

The accompanying illustration shows the results obtained, although it is probable that it will suffer some loss of detail in the process of reproduction. —*John J. Woolfenden, Engineering Staff, Smith, Hinchman & Grylls, Inc., Detroit.*

WASHINGTON NEWS

Summarized by Loring F. Overman; Military Refrigeration Peak Passed, Food Processors Are First to Benefit; Easing of Heat Controls by 1944-5.

The refrigerating industry's biggest customer, the military forces, passed the peak of its program with the turn of the year, but hardly had the delivery curve started its downward glide before another major customer appeared to take up the slack. This time it was the nation's civilian food industry, with a program calling for $36,965,680 worth of equipment for replacement, conversion and expansion during 1944 and the first quarter of 1945.

The program, presented to the War Production Board with favorable recommendations by the War Food Administration, promises to require virtually all of the industry's production capacity not needed for military requirements. Starting during the second quarter with $6,600,000 in construction authorized (43% of the prewar rate of construction during the second quarter), the program builds up to give a total production for the year ending March 31, 1945, of 58.5% of prewar normal. Prewar production of refrigeration for food processors was $63,551,840 in 1937 and $62,715,920 in 1939. It is anticipated total authorized construction for the year will amount to $36,965,680.

The projected requirements cover all refrigeration needs for protecting or processing of foods from the farms through all food processing, all ice manufacturing and cold storage—all needs up to the distributing level. Neither domestic refrigeration, nor refrigeration in retail food stores, wholesale establishments, public eating places, hospitals, hotels or institutions is included.

As outlined by the War Food Administration, with the cooperation of the Industry Task Committee of the commercial and industrial refrigeration industry, the program broadly defines replacement, conversion and expansion.

"Expansion," says the WFA report, "means replacement needs on existing equipment in maintaining existing food production. Conversion means addition or change in refrigeration equipment to meet new conditions of processing, for instance, production of boneless meat for Army and Navy requirements, and production of fish products for the armed forces. Expansion means additional refrigeration for processing facilities."

Authorized is a program calling for $12,297,049 for conversion and expansion and $24,668,631 for replacements. WPB allocations to manufacturers include 80,591 tons of carbon steel, 49 tons of alloy steel and 1,907,500 pounds of copper.

WFA Explains

"The urgent needs for refrigeration of food processors are greater than it is possible to produce at once," comments the War Food Administration summary of its presentation to the War Production Board. "The problem, therefore, becomes one of first things first, to frame requirements which give the maximum amount of help which is possible under present war conditions, distributed among segments of the total food production program as relative urgency of the different segments requires.

"This definite program for the utilization of this open capacity in manufacturing facilities for heavy refrigeration equipment as directed by the War Production Board with the sponsorship of the War Food Administration will have far-reaching results. It means saving of time and effort on the part of refrigeration equipment manufacturer and

Requests for additional metal allocations for the manufacture of heating controls, and for inclusion of heating controls in OWI's 1944-45 fuel conservation campaign publicity, were presented in Washington March 31 by this group of controls manufacturers and others. Howard Coonley, director of the WPB Conservation Division, acted as presiding officer, and William Crew presented the industry proposals.

FORGED

FORGED WELDING FITTINGS are strong, uniform, enduring. Tube Turns method of forging seamless steel tubing over curved expanding mandrels, thus distributing metal *evenly around the walls*, makes fittings still stronger, still more dependable. Metal structure is more dense and close-grained — finer even than that in the high quality seamless tubing from which TUBE TURN fittings are made. *This* manufacturing process is *exclusive* with TUBE TURNS.

TUBE-TURN welding fittings withstand extreme velocities, high pressures and corrosive wear *better* because they are TUBE-TURNS' forgings! Send for catalog and engineering data book No. 111.

TUBE TURNS (Inc.), Louisville, Kentucky. *Branch Offices: New York, Chicago, Philadelphia, Pittsburgh, Cleveland, Dayton, Washington, D. C., Houston, San Francisco, Seattle . . Distributors located in all principal cities.*

ARMY (E) NAVY M

TUBE-TURN

TRADE MARK

Welding Fittings and Flanges

users of the equipment alike in planning and acting for greater food production now.

"It means a transition from principally war work to work having after-the-war utility in the manufacturing of heavy refrigerating equipment, utilizing the open capacity which now exists and will continue to exist in greater amounts in succeeding quarters, and without necessity for reconversion of plants.

"On the several fighting fronts of friendly occupied countries, food to freed territory will be used as a weapon to help increase resistance behind enemy lines. The stocks of food which are being built up for this purpose require refrigeration. The extent to which needed refrigeration facilities are available will help hasten the end of resistance."

Status Quo in A-C

With heavy refrigeration production "spoken for" by the military and the War Food Administration program, and with F-22 refrigerant joining Freon-12 on the list of items withheld by WPB from the comfort air conditioning field, there was little indication during April that the coming summer will be anything but hot for any whose present equipment or refrigerating charges go awry.

By issuance of Conservation Order M-28-a on April 21, the War Production Board banned the use of F-22 (Monochlorodifluoromethane) in the same list of comfort air conditioning systems denied the use of Freon-12. The WPB explains that its action was taken with the expectation that owners of refrigerating and air conditioning systems that have been prohibited from obtaining a delivery of F-12 gas might attempt to substitute F-22, heretofore available without control. Even with the impositions of these new restrictions on deliveries of F-22, WPB estimates that inventories, at the present rate of authorized withdrawals, will drop to a critical low about July 1.

Assurances were given by WPB that with the restrictions in operation, an adequate supply of F-22 will be available for those systems designed specifically to use this gas for war production purposes.

The future of the air-conditioning industry, including proposals to make available some types of equipment now on the prohibited list, is scheduled for discussion, however, at the May 10 meeting of the General Refrigerating and Air-Conditioning Industry Advisory Committee, in Washington.

Heating Controls Considered

While April actions in Washington augured none too well for the summer cooling program, there were indications that early May would bring

Donald S. Woods, chief, Plumbing and Heating Branch, Office of Civilian Requirements, has under consideration proposals to expand the production of heating controls, and to permit the manufacture of oil burners and stokers for civilian use.

favorable action on proposals of heating control manufacturers that this industry be allocated a more important part in next winter's heating control and fuel saving program. Meeting in Washington late in March, the manufacturers requested allocation of materials for a greatly expanded program of heating control manufacture.

Allocation of materials for the construction of 600,000 control units had been approved by WPB, but the supplementary program, which would be several times as large, was still under consideration late in April on the desk of Donald S. Woods, chief, Plumbing and Heating Branch, Office of Civilian Requirements. Whether the program will be approved as presented could not be ascertained, but early action on a scale that would make heating controls an important part of the fuel conservation program of the 1944-45 season may be forecast.

If heating controls manufacturers are successful in securing allocations for an expanded production program, and in having OWI include heating controls among recommended heat-savers' publicity, they will be ready to tackle another Washington hurdle. This will be a move to have their products included in the Federal Housing Administration's new program to stimulate summer installation of more efficient heating facilities.

As presently drafted, the program provides that when authorized installations are made after April 1, no initial payment need be made until after November 30. Insulating materials, storm windows and weatherstripping are among the "heat savers" for which financing has been authorized, but manufacturers of heating controls are currently without this added inducement.

OCR Eyes Stokers, Burners

Also under consideration within the Office of Civilian Requirements are proposals to permit the construction of limit quantities of coal stokers and oil burners of types now prohibited. Reports on the stoker program indicate a possibility of favorable action by mid-May, but fourth-quarter allocations of materials for oil burner construction are considered unlikely. Scarcity of fractional horsepower motors is a deterring factor in both instances, and OCR is somewhat of the opinion that there are sufficient burners in inventory to take care of emergency replacement requirements.

Oil Rationing Continues

Mailing out of simple re-application forms early in June to domestic consumers, will signal the continuance, next season, of fuel oil rationing plans similar to those now in effect, the OPA has announced. Rationing is being planned on the assumption that the amount of oil available next winter will be the same as during the current season.

Some of the basic features of the present program which OPA expects to continue without change are:

1—The heating year will again be divided into five heating periods.

2—The present ten zones within the 33-state rationed area will be kept during 1944-1945.

3—Rations for R-1101 consumers will remain unchanged.

4—Industrial, commercial and governmental consumers using fuel oil for processing, and not for heat or hot water, will continue to receive the oil rations they need on a quarterly or semi-annual basis.

Grilles Studied

Registers and grilles for warm air heating systems are in short supply according to the newly organized Warm Air Register and Grille Industry Advisory Committee, the War Production Board announced on April 21.

The Committee agreed that a limitation order was needed to provide for production of registers and grilles on the basis of stated requirements from claimant agencies. A proposed order, basing production on a percentage of a base year's production, was discussed by the Committee.

Under the present production-set-up, no requirements are established. Production of registers for warm air heating systems is permitted under the Iron and Steel Order, M-126, but only Bessemer or top cut steel can be used and production is confined to labor areas 3 and 4.

Grille production is prohibited under Order M-126 except for those made for use on shipboard.

The prohibition on the manufacture of grilles has meant that in some instances registers are being installed where grilles, which use less metal, would suffice, committee members said.

ANGLE FACTORS FOR RADIANT HEATING AND COOLING

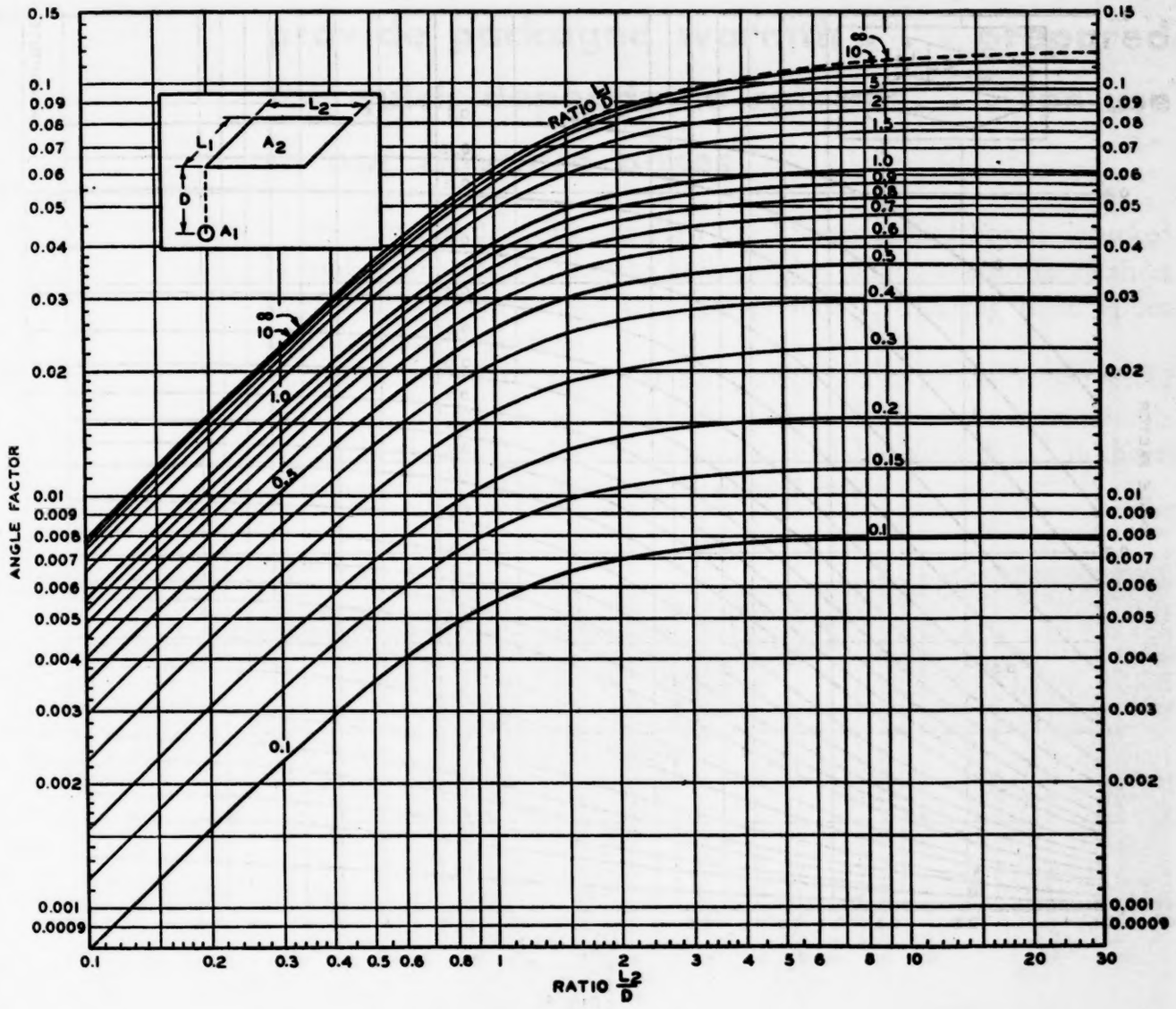

Fig. 3

Charts shown on this sheet and on Reference Data 267-268 and 271-272 give the values of angle factors for radiant heating or cooling calculations. All are from a study by the College of Engineering, Cornell University, as reported in Bulletin 32 of the Cornell University Engineering Experiment Station, entitled "Radiant Heating and Cooling, Part 1," by C. O. Mackey, L. T. Wright, Jr., R. E. Clark, and N. R. Gay, and presented here by permission. Angle factor is defined on Reference Data 267-268.

Figs. 3 and 4, on this sheet, cover equal emitting and intercepting areas opposite and parallel (Fig. 3), and adjacent and perpendicular areas with one edge in common (Fig. 4).

In Fig. 3, $\frac{L_1}{D}$ and $\frac{L_2}{D}$ are interchangeable, while in Fig. 5 $\frac{L_1}{W}$ and $\frac{L_2}{W}$ are *not* interchangeable.

USE OF CHARTS

Problem: The side (long) wall of a room 10 x 40 ft in plan with a 20 ft ceiling is emitting 30,000 Btu per hr. How much heat is intercepted by the (a) opposite wall; (b) floor; (c) ceiling; (d) adjacent end walls?

Solution: The angle factor for the opposite wall is found by using Fig. 3. Ratio $\frac{L_1}{D} = \frac{20}{10} = 2$; $\frac{L_2}{D} = \frac{40}{10} = 4$. From Fig. 3, angle factor is 0.51, so that (a) is 30,000 x 0.51 = 15,300 Btu per hr.

The floor is adjacent to the side wall, so that Fig. 4 applies. Ratio $\frac{L_2}{W} = \frac{10}{40} = .25$; $\frac{L_1}{W} = \frac{20}{40} =$ 0.5, so that, from Fig. 4, angle factor is 0.165, and (b) equals 30,000 x 0.165 = 4,950 Btu per hr each. Obviously, the ceiling is the same so that (c) also is 4,950 Btu per hr.

(Continued on other side)

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ANGLE FACTORS FOR RADIANT HEATING AND COOLING

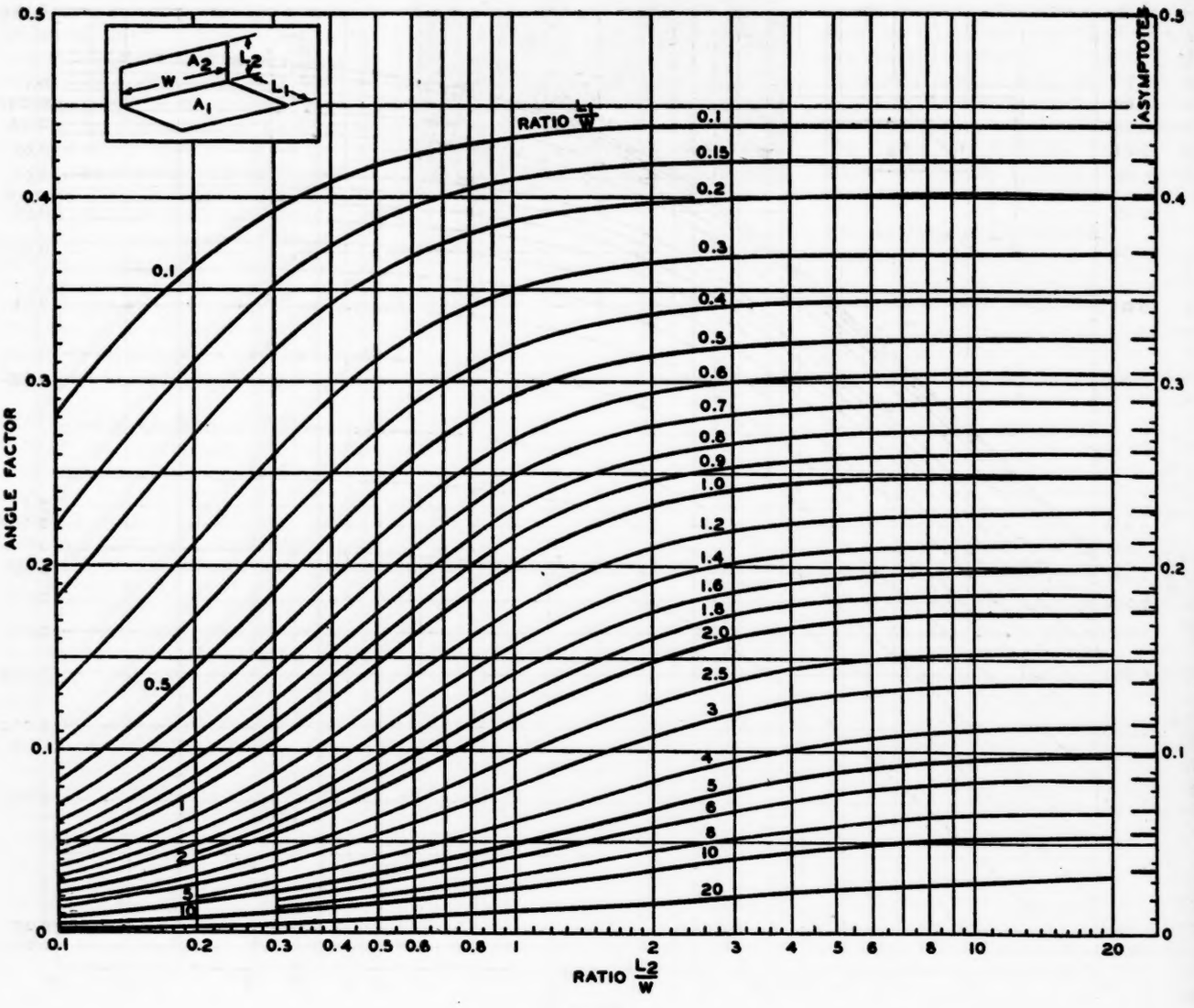

Fig. 4

In the case of the end walls, ratio $\frac{L_2}{W}$ becomes $\frac{10}{20}$ = 0.5 and $\frac{L_1}{W} = \frac{40}{20} = 2$. From Fig. 4, the angle factor is 0.08. Each end wall then intercepts 30,000 x 0.08 = 2,400 Btu per hr.

Examples of more complex arrangements of surfaces which can be solved by use of Figs. 3 and 4 are given on Reference Data 271-272.

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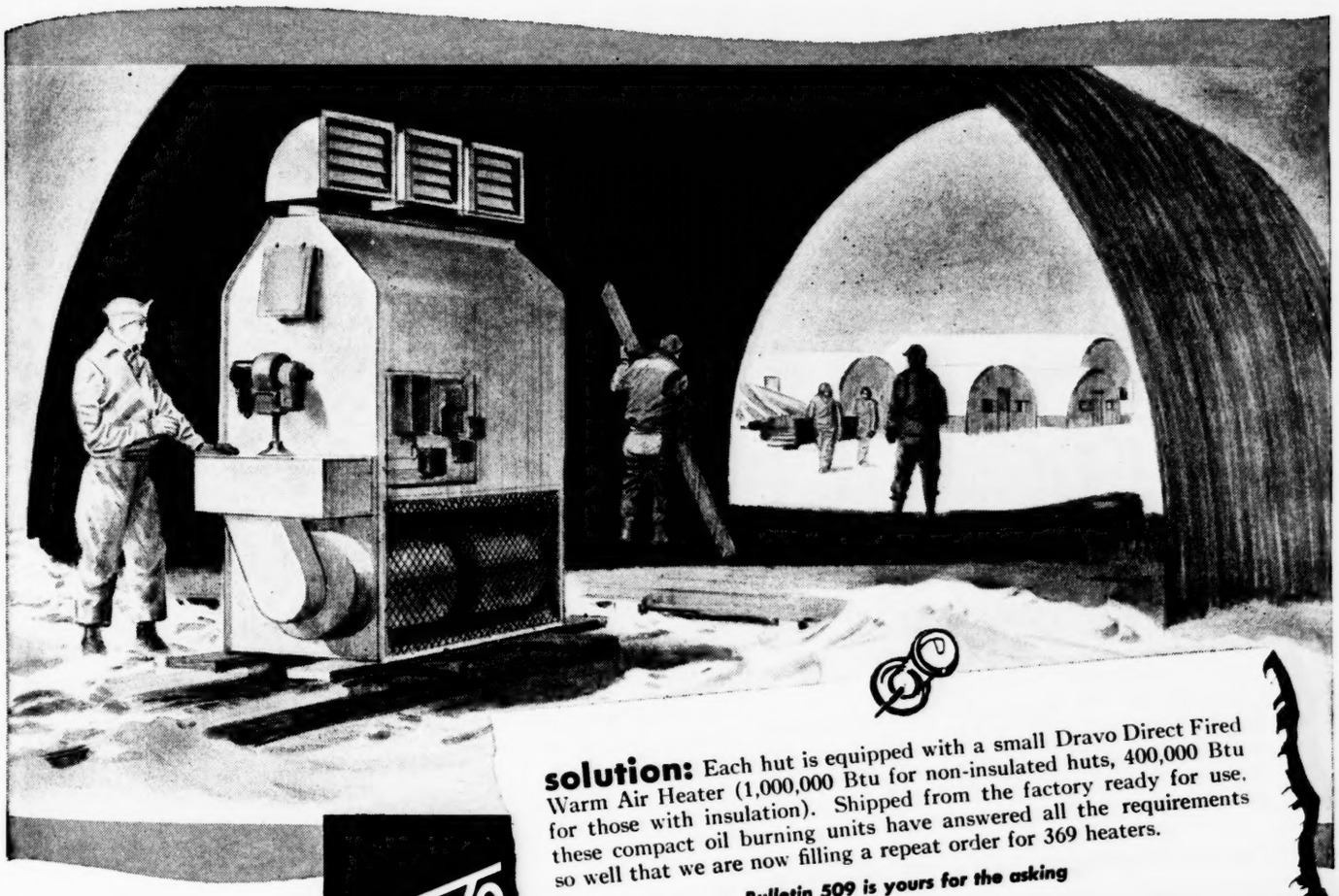
global problem:

provide packaged warmth . . . prepared for quick dependable set-up . . . for use in our advance bases

As Advance Base units of the United States Armed Forces debarked in cold regions throughout the globe, shelter igloos of corrugated sheet steel were quickly erected to house personnel. Heating these igloos posed a complex problem.

The heating unit for such an assignment had to be easy to move and install . . . simple to operate, light, efficient, built of the most reliable materials and equipped with the most dependable controls . . . in short, as compact and self-sufficient as a can of K ration.



solution: Each hut is equipped with a small Dravo Direct Fired Warm Air Heater (1,000,000 Btu for non-insulated huts, 400,000 Btu for those with insulation). Shipped from the factory ready for use, these compact oil burning units have answered all the requirements so well that we are now filling a repeat order for 369 heaters.

Bulletin 509 is yours for the asking

DRAVO

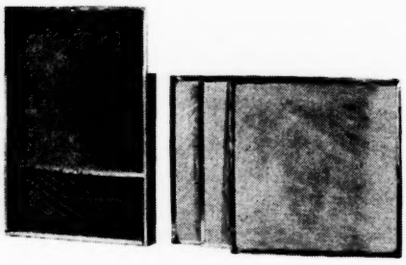
Heating

DRAVO CORPORATION, PITTSBURGH (22)

NEWS OF EQUIPMENT AND MATERIALS

Oil Filter

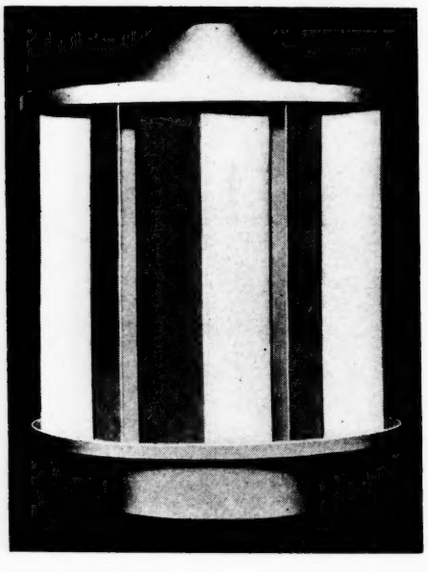
NAME—Badger oil filter.
PURPOSE—For use around production machinery to eliminate oil-laden air from going into the ventilation and air conditioning ducts, thus eliminating a potential fire hazard and the



need for shutdowns while cleaning ducts.
FEATURES—A special filter mesh with expanded metal screen on front and fibre glass or paper in the back, stops both dust and oil.
SIZES AND CAPACITIES—At present it is available in 1 and 2 in. sizes for capacities from 640 to 1000 cfm.
MADE BY—*Badger Manufacturing and Sales Company, 331 East Brown St., Milwaukee 12, Wis.*

Wind-Actuated Exhauster

NAME—Agitair exhauster.
PURPOSE — To provide positive ventilation regardless of wind direction or velocity. For use with gravity and mechanical exhaust systems.
FEATURES—No non-moving parts are necessary. The unit is weather-proof and light-proof and is said to provide positive elimination of down draft.



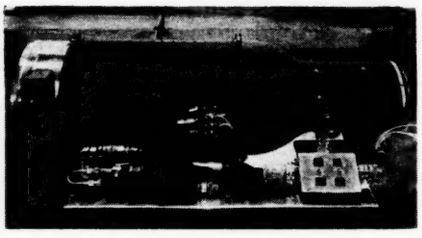
Units with water-tight dampers are made for marine use.
MADE BY—*Air Devices, Inc., 17 East 42nd St., New York 17, N. Y.*

Dial Thermometer with Plastic Case

NAME—4½ in. dial thermometer with plastic case.
PURPOSE — Mercury actuated instrument to withstand severe operating conditions. This unit is adapted to installations requiring a long length of tubing between bulb and instrument.
FEATURES — Plastic case is resistant to corrosion and shock. Metal dial is finished in black with white figures.
MADE BY—*Taylor Instrument Companies, P. O. Box 110, Rochester 1, N. Y.*

Aircraft Heater

NAME—South Wind heater.
PURPOSE—To heat airplanes, particularly when planes are flying at high altitudes. Heaters have also been used to speed the drying of laundry.



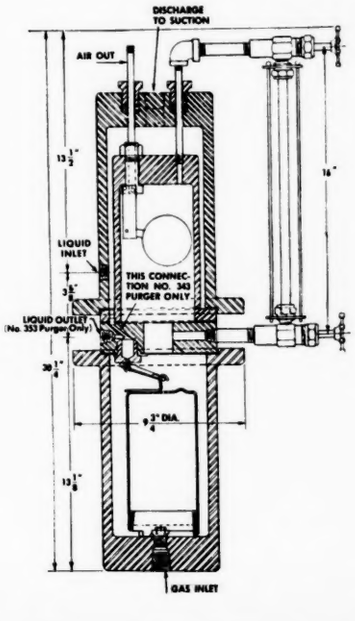
drying parachutes, and for heating shelters.
FEATURES—Design uses the features of accelerating flow, spiral heat exchanger. Heater is completely hermetically sealed. Unit has small combustion chamber but can deliver 200,000 Btu per hour. Company hopes to adapt unit for home heating.
MADE BY — *Stewart Warner Corporation, Diversey at Wolcott, Chicago, Ill.*

Aircraft Ducts

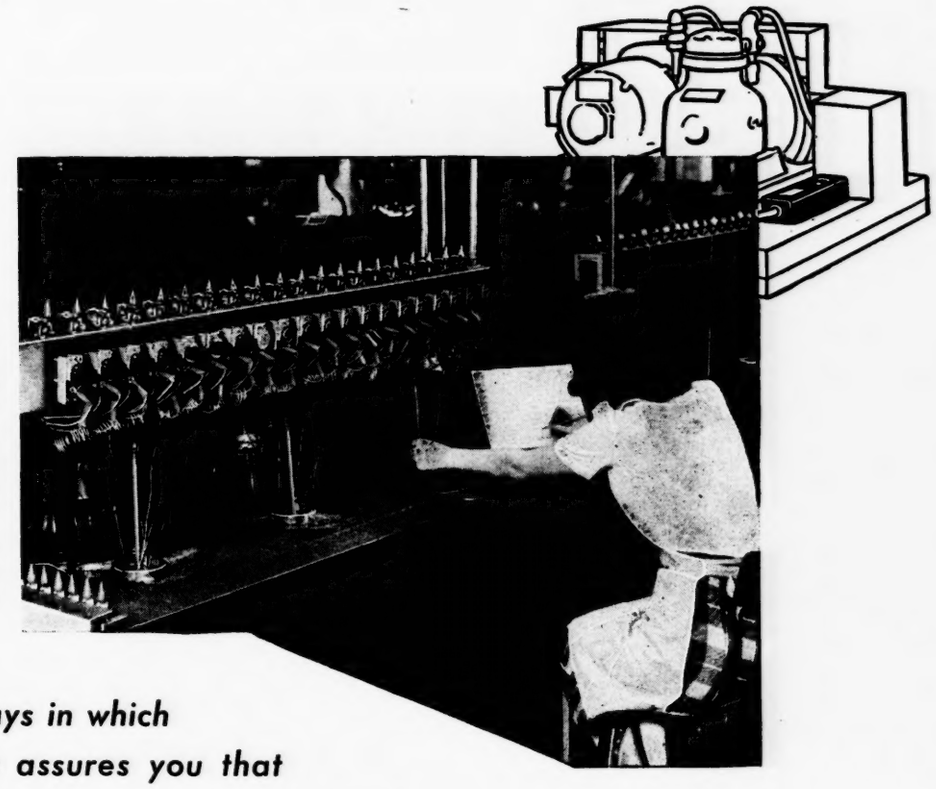
NAME—Air-duct systems for aircraft.
PURPOSE—A duct system for aircraft using a minimum of metal.
FEATURES — Manufacturer has developed a material made of fabric, asbestos, and a synthetic coating of resin which makes possible lightening of the material used on heating and ventilating air duct systems by over 10%. Material can be twisted and turned or completely deformed and returned to original shape without effort. Maker claims that a 1000 unit order which formerly employed 40 men for two shifts at 8 hours each was turned out using this system with a net saving of 320 man hours per day. System is said to allow material to be formed into radii and intricate angles and shapes for fittings in a matter of minutes. Ducts are presently being used for heating carburetors as turbo cooling duct, header ducts, generator blast tubes, fire wall seals and other working parts on planes. Applications are also important for cooling cargo ships. In post-war period applications are expected in mobile equipment as well as buildings.
MADE BY—*United States Rubber Company, Rockefeller Center, N. Y.*

Armstrong Purger

NAME—Refrigerant purger.
PURPOSE—For removing air and other non-condensible gases from refrigerating systems.
FEATURES—Made of forged steel, designed for high pressure CO_2, ammonia and freon system, and for service where engineers prefer all-steel construction. Purger is hooked up to both condenser and receiver and is reported to keep system free of non-condensibles with no appreciable loss of gas.
LITERATURE—Bulletin No. 160.
MADE BY—*Armstrong Machine Works, Three Rivers, Michigan.*



LEAVING NOTHING TO CHANCE



One of the many ways in which White-Rodgers assures you that every control will perform as promised.

8 EXCLUSIVE FEATURES OF WHITE-RODGERS HYDRAULIC-ACTION TEMPERATURE CONTROLS

1. May be mounted at any angle or position, above, below or on level with control point.
2. Hydraulic-Action Principle incorporating solid-liquid filled bulb and capillary provides expansion force comparable to that of a metal bar.
3. Diaphragm motion uniform per degree of temperature change.
4. Power of solid-liquid charge permits unusually sturdy switch construction resulting in positive contact closure.
5. Heavier, longer-wearing parts are possible because of unlimited power.
6. Dials are evenly and accurately calibrated over their entire range because of straight-line expansion.
7. Controls with remote bulb and capillary are not sensitive to change in room temperature. Accuracy of control is not affected by temperature changes in surrounding area.
8. Not affected by atmospheric pressure. Works accurately at sea level or in the stratosphere without compensation or adjustment.

Part of the final check of every White-Rodgers temperature control is the cold bath immersion test. Here, in constantly circulating fluid of predetermined temperature the controls are checked for positive switch contact and reaction to temperature changes. At this stage, too, final adjustment of the dial is made so that the calibration thereafter is always accurate.

This, and other testing equipment, has been operating since the first White-Rodgers Control was built — operating to assure accurate temperature control to you — and to safeguard White-Rodgers' reputation in the heating and refrigeration fields.

HYDRAULIC ACTION CONTROL — MEMBER I.C.I. INDOOR CLIMATE INSTITUTE

WHITE-RODGERS
ELECTRIC CO.

1207E Cass Ave. St. Louis, Mo.

Controls for Heating • Refrigeration • Air-Conditioning

Degree-Days for March, 1944

HEATING AND VENTILATING'S 16th year of publication of monthly degree-day data

City	Monthly Degree-Days			Cumulative Degree-Days[1]			Year[2]
	Degree-Days, March 1944	Degree-Days, March, 1943	Degree-Days, March, Normal	Season, 9/1/43-3/31/44	Season, 9/1/42-3/31/43	Season, Normal, 9/1-3/31	Normal, 9/1-6/30
Abilene, Texas	366	333	273	2424	1855	2034	2061
Albany, New York	1116	1039	980	6316	6350	5848	6580
Albuquerque, New Mexico	639	519	527	4389	3434	3970	4298
Alpena, Michigan	1227	1297	1213	6622	6934	6873	8299*
Anaconda, Montana	1182	1275	1081	6581	6812	6737	8357**
Asheville, North Carolina	574	634	555	3829	3722	3831	4232
Atlanta, Georgia	395	470	388	2724	2689	2758	2890
Atlantic City, New Jersey	785	743	806	4323	4120	4437	5176
Augusta, Georgia	279	339	273	2129	2056	2137	2161
Baker, Oregon	932	886	880	5693	5795	5904	7163
Baltimore, Maryland	719	634	701	4059	3909	4163	4533
Billings, Montana	1111	1221	955	5654	6381	6209	7119
Binghamton, New York	1067	948	995	6160	5848	5960	6808
Birmingham, Alabama	309	415	260	2705	2353	2283	2352
Bismarck, North Dakota	1435	1403	1283	7130	8451	8152	9192
Block Island, Rhode Island	923	896	911	4879	4920	4678	5788
Boise, Idaho	827	780	651	5123	4981	4881	5552
Boston, Massachusetts	956	902	908	5257	5264	5230	6045
Bozeman, Montana	1153	1287	1096	6650	6939	6993	8521**
Buffalo, New York	1084	1076	1032	6053	6022	5800	6822
Burlington, Vermont	1227	1163	1088	7084	7010	6584	7514
Butte, Montana	1240	1337	1048	7113	7425	6683	8272
Cairo, Illinois	546	656	539	3677	3624	3708	3909
Canton, New York	1226	1185	1160	7126	7237	7002	8020
Charles City, Iowa	1143	1237	1024	6531	7234	6752	7588
Charleston, South Carolina	212	315	242	1775	1802	1733	1769
Charlotte, North Carolina	441	477	428	2919	2850	2961	3120
Chattanooga, Tennessee	458	507	415	3307	3063	2974	3118
Cheyenne, Wyoming	1147	1136	995	6133	5942	6174	7466
Chicago, Illinois	1014	1019	902	5655	5965	5178	5957
Cincinnati, Ohio	764	783	676	4522	4542	4351	4684
Cleveland, Ohio	959	883	930	5282	5200	5371	6155
Columbia, Missouri	762	808	694	4701	4616	4597	4922
Columbia, South Carolina	332	367	301	2329	2330	2301	2364
Columbus, Ohio	854	833	778	4880	4851	4891	5398
Concord, New Hampshire	1140	1110	1011	6681	6674	6332	7353
Concordia, Kansas	939	872	735	4992	5040	4908	5315
Dallas, Texas	319	440	267	2333	2265	2247	2256
Davenport, Iowa	983	973	893	5521	5921	5718	6289
Dayton, Ohio	897	846	744	5220	4837	4787	5264
Denver, Colorado	941	884	800	4917	4604	5073	5874
Des Moines, Iowa	1034	1022	890	5699	6011	5825	6384
Detroit, Michigan	1050	967	973	5752	5836	5691	6490
Devils Lake, North Dakota	1545	1522	1323	8044	9127	8694	9970
Dodge City, Kansas	828	831	688	4905	4476	4646	5035
Dubuque, Iowa	1060	1071	958	5957	6444	6152	6790
Duluth, Minnesota	1341	1454	1265	7717	8359	7945	9443
Eastport, Maine	1162	1136	1110	6615	6675	6612	8520**
Elkins, West Virginia	826	825	763	5218	4833	5019	5697
El Paso, Texas	339	289	282	2690	2146	2383	2428
Ely, Nevada	1105	497	—	6533	5588	—	—
Erie, Pennsylvania	1019	931	973	5546	5414	5407	6273
Escanaba, Michigan	1255	1367	1262	6908	7426	7290	8771*
Evansville, Indiana	688	773	620	4376	4369	3968	4244
Fort Smith, Arkansas	439	557	397	3053	2974	3054	3147
Fort Wayne, Indiana	1021	976	818	5838	5849	5321	5925
Fort Worth, Texas	319	446	217	2290	2267	2121	2148
Fresno, California	314	267	316	2322	2291	2199	2334
Galveston, Texas	113	203	78	1141	1039	1016	1016
Grand Junction, Colorado	768	690	672	4802	4400	5046	5548
Grand Rapids, Michigan	1057	1034	964	5773	5927	5827	6535
Green Bay, Wisconsin	1183	1260	1125	6636	7139	6903	7825
Greensboro, North Carolina	593	585	474	3756	3514	3319	3529
Greenville, South Carolina	453	503	446	2949	2897	3185	3380
Harrisburg, Pennsylvania	866	754	803	4973	4741	4880	5375
Hartford, Connecticut	962	935	887	5600	5575	5303	6036
Hatteras, North Carolina	412	443	465	2535	2277	2316	2571
Havre, Montana	1310	1302	1169	6406	7551	7557	8700
Helena, Montana	1184	1363	1004	6720	7420	6615	7898
Houston, Texas	133	212	65	1278	1196	1157	1157
Huron, South Dakota	1269	1229	1092	6874	7497	7167	8004
Indianapolis, Indiana	830	906	756	4878	5100	4855	5298
Kansas City, Missouri	801	819	691	4656	4657	4644	4956
Kewanee, Illinois	1020	1059	884	5833	6229	5524	6139
Knoxville, Tennessee	482	586	496	3410	3396	3460	3670
La Crosse, Wisconsin	1096	1256	1033	6671	7169	6611	7322
Lander, Wyoming	1191	1219	1028	7306	6569	6694	7947

[1]Cumulative data identical with monthly figures for September only. In subsequent months, cumulative figures will show record for whole heating season to and including month in question.

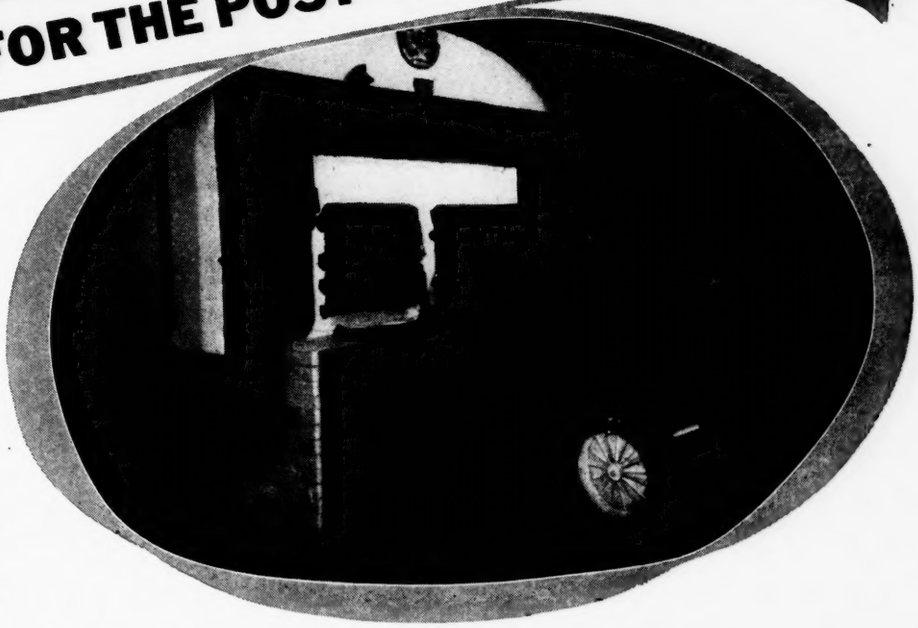
[2]Figures in this column are normal totals for a complete heating season, September to June, incl.

Figures in this table, with eight exceptions, based on local weather bureau reports. Exceptions are Utica, Lewiston, Kewanee, and Sioux City, figures for which are furnished through the courtesy of Coke Sales Department, Central New York Power Corp., Utica, N. Y.; Norman E. Ross, Bursar, Bates College, Lewiston, Me.; J. M. Hartman, Engineering Department, Kewanee Boiler Corp., Kewanee, Ill., and Alfred R. Wagstaff, Engineer, Sioux City Foundry and Boiler Co., Sioux City, Iowa, respectively; Anaconda, Bozeman, Butte and Livingston, Mont., through the courtesy of the Montana Power Company.

[Table concluded on page 86]

Boiler Plant..FOR THE POST-WAR RETAIL STORE

Built immediately pre-war the W. T. Grant Co. store in Portland, Maine, is heated by a 16 section, number 60 SMITH, cast-iron, stoker fired boiler.



How 200 H. B. Smith boiler installations in W. T. Grant Co. stores are setting a standard for post-war heating . . . . . .

By necessity extremely conscious of overhead costs, chain store management selects equipment with the highest consideration for its eventual "cost of use." The annual fuel bills, for example, weigh far heavier than do a few extra dollars in the original cost of the heating equipment.

It is for this reason that the W. T. Grant Co. installed H. B. SMITH Boilers in many of its nationally known variety stores. W. T. Grant Co. now has approximately 200 stores heated by H. B. SMITH boilers. Fuel expense has been uniformly low. Maintenance costs have been negligible.

It is our prediction that the boiler plant heating the post-war chain store will closely resemble the best installations of 1941. Specifiers and installers who will be judged by the *annual expense* of boiler operation will do well to profit by W. T. Grant's experience and specify a known quantity in boiler performance . . . H. B. SMITH.

Complete engineering data and specifications of H. B. SMITH boilers available for this type of construction are filed in the Domestic Engineering Catalogue Directory and Sweet's "Engineering," or will be furnished on request.

H.B. Smith
CAST-IRON BOILERS

THE H. B. SMITH COMPANY, INC. • WESTFIELD, MASS.
Branch Offices and Sales Representatives in Principal Cities

Degree-Days for March, 1944 (Concluded)

HEATING AND VENTILATING'S 16th year of publication of monthly degree-day data

City	Monthly Degree-Days			Cumulative Degree-Days[1]			Year[2]
	Degree-Days, March, 1944	Degree-Days, March, 1943	Degree-Days, March, Normal	Season, 9/1/43-3/31/44	Season, 9/1/42-3/31/43	Season, Normal, 9/1-3/31	Normal, 9/1-6/30
Lansing, Michigan	1120	1063	1035	6307	6329	6237	7048
Lewiston, Maine	1165	1137	1093	7056	6784	6625	7707
Lincoln, Nebraska	1036	949	840	5387	5531	5483	5999
Little Rock, Arkansas	417	554	353	2943	2918	2733	2811
Livingston, Montana	1131	1140	967	5834	6223	5985	7205
Los Angeles, California	179	194	239	1125	951	1255	1504
Louisville, Kentucky	682	707	589	4034	4087	3916	4180
Lynchburg, Virginia	619	577	564	3652	3520	3707	3980
Macon, Georgia	254	350	260	2223	2116	2168	2201
Madison, Wisconsin	1147	1163	1054	6401	6864	6611	7429
Marquette, Michigan	1284	1346	1249	6875	7335	7164	8693*
Memphis, Tennessee	409	567	384	3025	2996	2854	2950
Meridian, Mississippi	246	350	245	2239	2092	2136	2160
Milwaukee, Wisconsin	1100	1116	1023	6260	6598	6208	7245
Minneapolis, Minnesota	1212	1286	1094	6765	7608	7044	7850
Modena, Utah	919	763	827	5672	5103	5591	6562
Montgomery, Alabama	211	314	208	1943	1846	1884	1884
Nantucket, Massachusetts	906	883	899	4855	4904	4811	5957
Nashville, Tennessee	503	610	477	3425	3370	3327	3507
New Haven, Connecticut	949	859	899	5372	5108	5129	5895
New Orleans, Louisiana	100	210	59	1192	1184	1024	1024
New York, New York	872	791	837	4762	4557	4706	5347
*Nome, Alaska	1508	1568	1660	8268	9134	8886	14580**
Norfolk, Virginia	532	505	521	3173	2849	3104	3350
North Head, Washington	647	621	623	3422	3644	3755	5452**
North Platte, Nebraska	1060	1004	875	5637	5428	5681	6366
Oakland, California	359	320	363	2288	2261	2392	3143**
Oklahoma City, Oklahoma	551	627	465	3383	3361	3451	3613
Omaha, Nebraska	1051	985	868	5670	5775	5633	6131
Oswego, New York	1121	1044	1060	6154	6065	5993	7088
Parkersburg, West Virginia	763	746	670	4624	4370	4371	4775
Peoria, Illinois	952	923	862	5608	5621	5535	6109
Philadelphia, Pennsylvania	778	699	756	4361	4278	4385	4855
Phoenix, Arizona	220	77	152	1468	972	1405	1405
Pittsburgh, Pennsylvania	833	776	787	4881	4635	4734	5235
Pocatello, Idaho	969	923	843	6049	5603	5696	6655
Portland, Maine	1113	1098	1017	6637	6605	6105	7218
Portland, Oregon	551	555	558	3403	3498	3732	4469
Providence, Rhode Island	911	862	890	5124	5123	5206	6015
Pueblo, Colorado	829	865	732	5181	4652	4872	5514
Raleigh, North Carolina	503	476	446	3218	2943	3051	3234
Rapid City, South Dakota	1325	1229	1010	6291	6508	6150	7118
Reading, Pennsylvania	840	743	794	4794	4663	4876	5389
Redding, California	290	328	344	2264	2275	2295	2451
Reno, Nevada	790	656	753	5006	4435	4902	5892
Richmond, Virginia	608	548	543	3647	3404	3449	3695
Rochester, New York	1096	1025	1029	6182	6060	5854	6732
Roseburg, Oregon	560	494	546	3472	3212	3636	4428
Roswell, New Mexico	433	439	428	3383	2810	3304	3484
Sacramento, California	291	303	357	2248	2259	2393	2653
St. Joseph, Missouri	877	873	682	4968	5026	4803	5161
St. Louis, Missouri	735	761	657	4280	4271	4309	4585
Salt Lake City, Utah	891	770	722	5407	4912	4866	5555
San Antonio, Texas	176	243	74	1644	1402	1202	1202
San Diego, California	191	158	251	1120	961	1350	1645
Sandusky, Ohio	964	905	915	5316	5367	5299	6208
San Francisco, California	286	290	353	1845	1940	2123	3264**
Sault Ste. Marie, Michigan	1394	1498	1314	7515	6472	7629	9285**
Savannah, Georgia	142	242	167	1455	1476	1490	1490
Scranton, Pennsylvania	981	893	893	5656	5491	5445	6129
Seattle, Washington	589	602	620	3441	3668	3917	4934**
Sheridan, Wyoming	1162	1284	1048	6332	6451	6837	8008
Shreveport, Louisiana	237	374	202	2145	2056	1938	1938
Sioux City, Iowa	1133	1078	967	6229	6537	6245	6898
Spokane, Washington	867	904	778	5381	5617	5485	6355
Springfield, Illinois	831	838	760	4926	4983	4951	5373
Springfield, Missouri	687	817	626	4356	4276	4149	4428
Syracuse, New York	1120	1023	1004	6293	6148	5984	6893
Tacoma, Washington	637	643	648	3819	3930	4086	5181**
Terre Haute, Indiana	794	817	663	4747	4761	4539	4872
Toledo, Ohio	1034	973	905	5826	5700	5372	6077
Topeka, Kansas	814	824	682	4621	4679	4635	4969
Trenton, New Jersey	842	763	735	4791	4639	4450	4933
Utica, New York	1195	1079	989	6708	6378	5955	6796
Valentine, Nebraska	1263	1181	980	6372	6390	6205	7039
Walla Walla, Washington	656	664	598	4470	4386	4274	4808
Washington, D. C.	688	610	694	4099	3889	4253	4626
Wichita, Kansas	746	812	648	4297	4466	4421	4673
Williston, North Dakota	1460	1451	1280	7177	8448	8238	9323
Winnemucca, Nevada	893	710	767	5432	4757	5411	6427**
Yakima, Washington	704	715	620	4820	5104	5053	5599

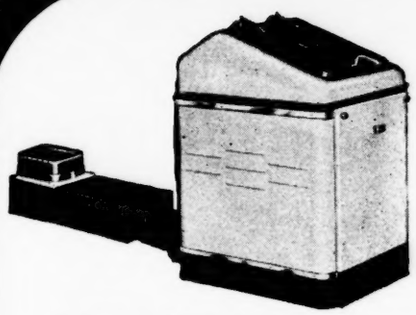
*Includes August. **Includes July and August.

[1]Cumulative data identical with monthly figures for September only. In subsequent months, cumulative figures will show record for whole heating season to and including month in question.

[2]Figures in this column are normal totals for a complete heating season, September to June, incl.

OLCOMB & HOKE

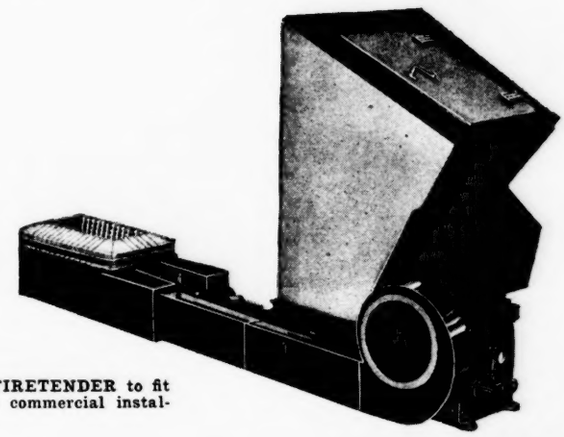
FIRE TENDERS



A full line of domestic models available for homes upon release by the W.P.B.

They Make Money for USERS... They Make Money for DEALERS

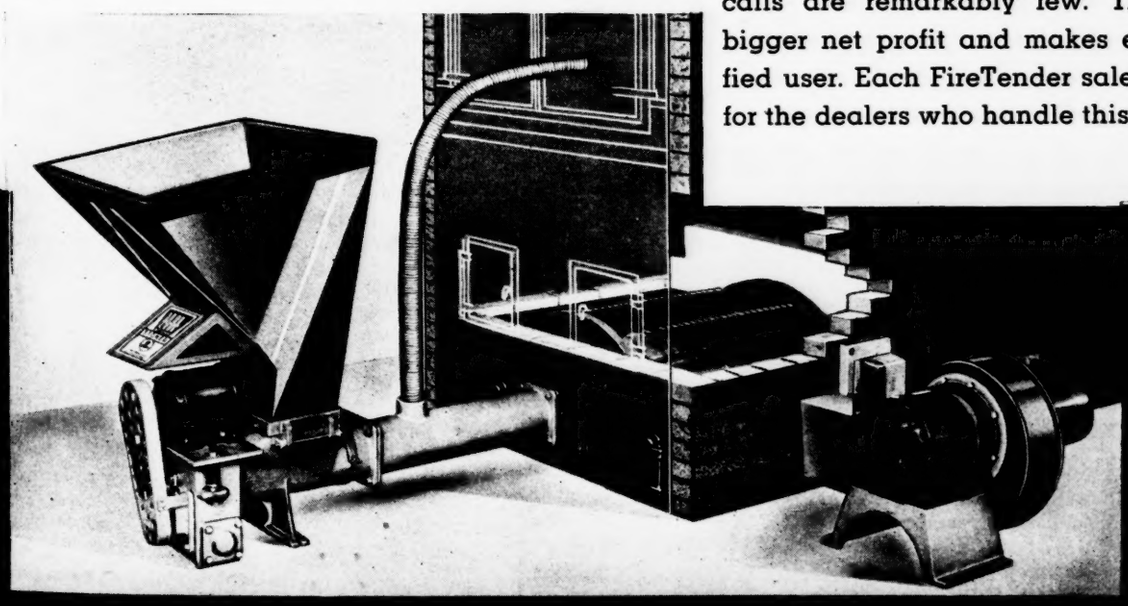
That's Why FIRETENDERS Are Popular With Both!



There is a **FIRETENDER** to fit the smallest commercial installation.

If you are a **USER** your FireTender renders a money and manpower saving service which is actually measured in dollars multiplied by years of constant, scientific fueling. You know that your particular model FireTender is designed and built for exactly the kind and size of heating plant you operate. The FireTender line is a famous one and a leader in the stoker field.

If you are a **DEALER** you know that a good, honest income is possible from this complete, many-sized stoker line... and that because of their splendid design, construction and operation your service calls are remarkably few. This makes you a bigger net profit and makes every user a satisfied user. Each FireTender sale makes more sales for the dealers who handle this famous stoker line.



ARMY E NAVY

STOKER MANUFACTURERS ASSOCIATION SMA

HOLCOMB & HOKE MFG. CO.

INDIANAPOLIS INDIANA

NEWS OF THE MONTH

Virginia Taxes Sales Agents

RICHMOND, VA.—Certain tax codes in the State of Virginia are sharply affecting the activities of manufacturers' salesmen and representatives in that area, according to Henry L. Pelouze of the Pelouze Sales Company. The state of Virginia and the cities of Richmond and Norfolk, at the present time, have tax codes which are being interpreted as classifying manufacturers' representatives and salesmen, regardless of the form of remuneration, as agents, sales agents, agencies, commission merchants or brokers and liable to taxes under the various codes. In addition to current taxes, the salesmen are being assessed for three years omitted taxes plus penalty and interest.

The State of Virginia taxes such salesmen's commissions on the basis of $25 on commissions less than $2,000 plus 50c per $1,000 on the next $8,000 and $1 per hundred on all commissions in excess of $10,000 gross income. The city of Richmond taxes such salesmen $50 and ½ of 1% of the gross earnings, receipts, fees or commissions in excess of $1,000. A similar situation exists in the city of Norfolk which taxes, among other things, building materials, and collects a tax of $50 and ½ of 1% of all commissions, gross profits or compensation received in said business.

According to Mr. Pelouze these codes are resulting in a handicap to manufacturers and their representatives in the Virginia territory and eventually may prevent manufacturers from doing business in Virginia for this reason.

A suggestion was made by Mr. Pelouze that manufacturers should make prompt investigation of this tax situation, and should take the necessary steps to protect their interests.

Carter Appointed to Smoke Job

ST. LOUIS—Appointment of James H. Carter, mechanical engineer, as acting smoke commissioner to succeed Robert M. Boyles was announced April 12 by Director of Public Safety Harry D. McBride.

A deputy smoke commissioner since September 1, 1938, Mr. Carter is a graduate of the Washington University School of Engineering and Architecture.

Mr. Carter's appointment followed the resignation of Mr. Boyles, who was criticized for relaxing the smoke elimination ordinance during the coal shortage to permit the Terminal Railroad Association to use high volatile coal for a few months in February.

Chicago Group Attacks Fuel Waste

CHICAGO—Members of the Chicago steering committee for the National Fuel Efficiency Program, conducted in cooperation with the Bureau of Mines, met here April 3 to plan its attack on the job of conserving coal, oil, and gas in this area. An entirely voluntary enterprise, the program contemplates determination of all possible sources of fuel waste in plants and buildings in the Chicago district and suggestions to users for conserving fuel, a vital wartime commodity. A subcommittee is classifying all industrial, commercial, and institutional users of the three fuels.

W. D. Langtry, president of the Commercial Testing and Engineering Co., is the Chicago coordinator for the drive. Members of his steering committee are F. H. Bird, engineer, Binkley Coal Co.; C. M. Burnam, Jr., editor, *Heating, Piping & Air Conditioning;* Frank Chambers, Chicago Smoke Inspector; H. C. Carroll, engineer, Commercial Testing and Engineering Co.; E. A. Dieterle, gas engineer; Rex E. Hieronymus, Aldis & Co.; John Howatt, chief engineer, Chicago Board of Education; Arlen Jennings, senior fuel engineer, U. S. Bureau of Mines; Harold F. Jones, chief lubrication engineer, Cities Service Oil Co.; Vernon G. Leach, engineer, Peabody Coal Co.; and Harold M. Toombs, chief engineer of the Stevens Hotel.

Coal-Fired Boiler Research Discussed at Joint Conference

COLUMBUS, OHIO—Coordinated research regarding improved utilization of bituminous coal was discussed at a joint conference of the Institute of Boiler and Radiator Manufacturers and the Heating Equipment and Residential Stoker Committees of Bituminous Coal Research, Inc., at Battelle Institute, Columbus, Ohio.

The meeting was called to determine what information on bituminous coal that would foster their mutual interests could be obtained by B.C.R. for the Institute of Boiler and Radiator Manufacturers. Trends in boiler manufacture, boiler performance, hand firing and stoker firing, and methods of testing and rating boilers were discussed.

J. F. McIntire, vice-president in charge of research, U. S. Radiator Corporation, presided over the conference, and H. N. Eavenson, president of B.C.R., J. E. Tobey, chairman of the B.C.R. Technical Advisory Board, and C. F. Hardy, chairman, B.C.R. committee on Heating Equipment, addressed the group. Each cited the need for cooperative effort to improve the utilization of coal in boiler heating equipment and pointed out the mutual advantages that might accrue from B.C.R.'s expanded research program.

Convenience of use and smokeless performance were considered requisites of postwar heating equipment. Heating plants for the small home of the future, it was believed, will be designed for 50,000 Btu per hour maximum rating. Improved workmanship and the liberal use of insulation in postwar home construction were foreseen.

Hand-fired boilers are expected to meet the needs of the small home owner whose heat requirements are too small to warrant a stoker. The principal problem is the design of fuel and combustion space to provide smokeless combustion and infrequent attention.

Automatic firing of residential boilers by clinker-type stokers presented a problem in boilers of small grate dimensions. Discussion of designs of new equipment to permit automatic firing of small boilers was scheduled for another meeting. Larger residential boilers have long been fired successfully with various types of stokers.

FHA – Insured Construction

WASHINGTON—Construction was started on 27,050 new privately financed dwelling units for war workers under the Federal Housing Administration's mortgage insurance program during the first quarter of 1944, compared with 33,785 started in the previous quarter and with 21,322 started in the first quarter of 1943, Commissioner Abner H. Ferguson has announced.

Family dwelling units completed under the FHA program during the first quarter of 1944 numbered 30,948 compared with 38,194 completed in the previous quarter and with 25,165 completed in the first quarter of last year.

(Continued on page 90)

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WHERE, WHEN, AND HOW YOU NEED IT

For permanent or temporary, for additional or emergency heating. Can easily be moved to other rooms or buildings. Automatic controls prevent heat-wastage. Direct heat outlets save fuel. Powerful blower spreads heat evenly without draft. May we give you detailed information on this flexible and economic way of heating?

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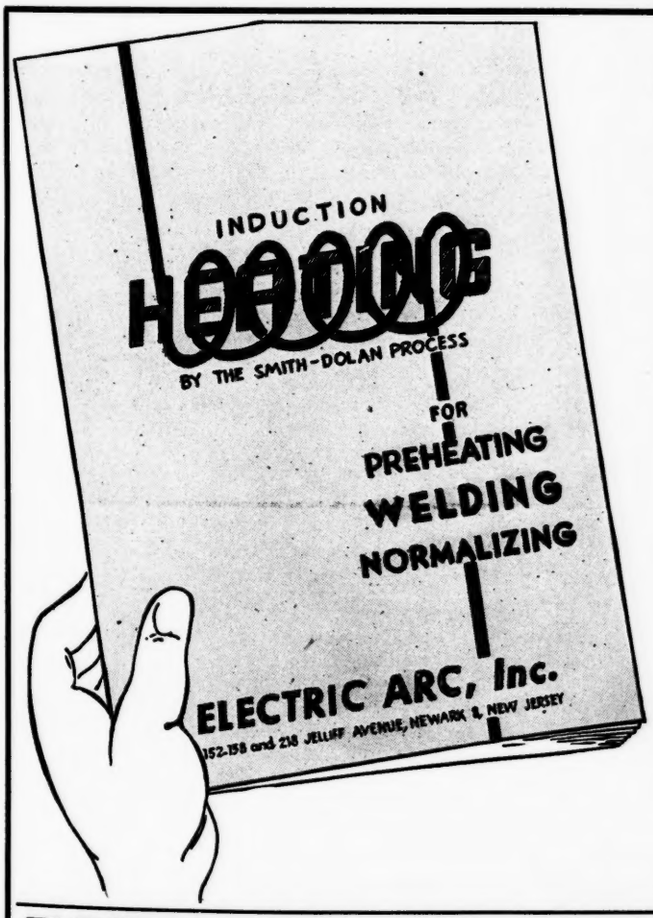

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(Continued from page 88)

I-B-R Engineers Review Research

COLUMBUS, OHIO—Higher standards of convenience and performance in postwar hot water and steam heating plants are indicated by research activities reviewed and discussed at a two-day meeting of the engineering representatives of The Institute of Boiler and Radiator Manufacturers here March 20-21.

At the meeting on March 20, reports were presented on the I-B-R Research Program at the University of Illinois and plans were outlined for the continuation of the program. The first draft of an installation guide based on the findings of the program were reviewed at this session. The second session was held at Battelle Memorial Institute March 21. At this meeting, attended by representatives of Battelle, Bituminous Coal Research, Inc., coal companies and coal-hauling railroads, there was an exchange of data and views on improved methods of firing bituminous coal, both manually and automatically, as well as related subjects such as grate design, coal sizing, and chimney heights.

Co-chairmen of the meeting at Battelle were Ralph A. Sherman, supervisor, fuels division, Battelle Memorial Institute, and J. F. McIntire, first vice-president, United States Radiator Corporation.

L. N. Hunter, vice-president and director, National Radiator Company, was chairman of the meeting of engineering representatives. Messrs. McIntire and Hunter presided in the absence of John P. Magos, Crane Co., who is chairman of the technical committee and advisory research committee of the I-B-R.

W. S. Harris, University of Illinois, presented a report illustrated by slides of the research work done at the I-B-R Research Home at the University during the 1943-1944 heating season. The objectives of the work were:

(1) To compare the operation of a gas-fired boiler having a net rating of 48,000 Btu per hour with that of an oil-fired boiler having a net rating of 63,000 Btu per hour;

(2) To compare comfort conditions produced by various types of panel heating systems with those produced by conventional radiators; and

(3) To determine the operating characteristics of a gas-fired system for three different gas input rates.

No significant difference could be noted in the comfort conditions produced within the house when the oil-fired boiler was replaced by a gas-fired boiler. With both boilers, the average floor to ceiling gradient was approximately 5½F when the outdoor temperature was 0F.

After a discussion of the future of the research program, the meeting reviewed the first draft of an installation guide for heating and piping contractors incorporating the findings of the I-B-R Research program. The copy of Installation Guide No. 1 was presented by H. F. Randolph, vice-president, International Heater Co.

This guide covers the installation of one-pipe forced circulation hot water heating systems for structures having a maximum heat loss of 60,000 Btu per hour. Data on the friction losses in pipe and fittings and on the heat emission of radiators attained at the University of Illinois has made possible the formulation of an installation guide for one-pipe forced circulation systems that will insure better operating systems at lower first cost and using less material.

Other subjects discussed were: average size of boilers for post-war houses, grate designs, use of sprinklers in ash pits, greater use of thermostatic controls for handfired furnaces, chimneys, treatment of coal to reduce dust, and design of boilers for stoker firing.

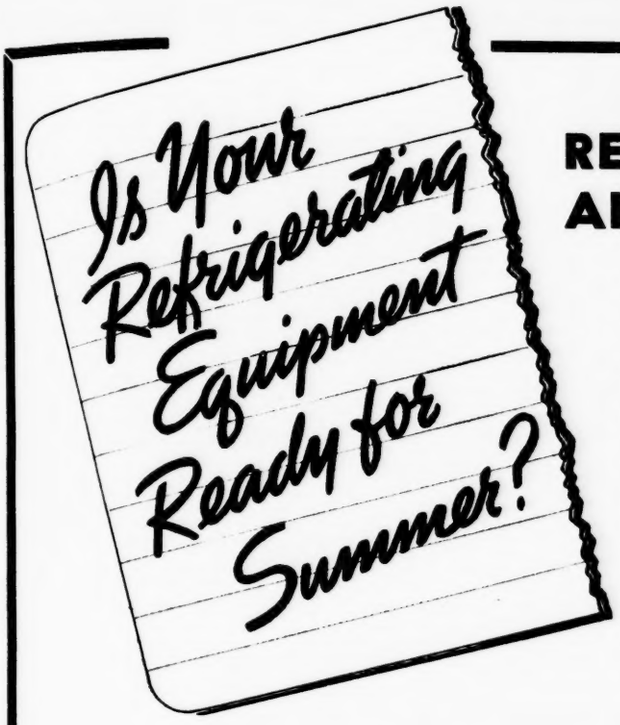
Institute Broadens Membership Basis

CHICAGO—Members of The Institute of Boiler and Radiator Manufacturers have approved an amendment to the constitution of the Institute which provides for two classes of membership, namely, member and associate member. This action was taken to provide for a united front for educational and promotional activities on behalf of steam and hot water heating.

Heretofore there has been only one class of membership which comprised the manufacturers of cast iron heating boilers and radiators. Associate membership will include manufacturers of other appliances or equipment related to the boiler and radiator industry or to the operation of steam or hot water heating systems.

(Concluded on page 92)

Joint Conference of the Institute of Boiler and Radiator Manufacturers and the Heating Equipment and Residential Stoker Committees of Bituminous Coal Research at Battelle Institute, Columbus, Ohio. Left to right at the table are C. F. Hardy, Ralph A. Sherman, J. F. McIntire, J. E. Tobey, and H. N. Eavenson.



WHITLOCK

REFRIGERATING EQUIPMENT AND ENGINEERING SERVICE

Warm weather will soon place a heavy load on your entire plant, and shut-downs will be costly. Whitlock Engineers will gladly advise on necessary repairs and suggest improvements to put your equipment at peak efficiency. Whitlock has the manufacturing facilities and steel plate, forged steel pipe flanges and steel pipe to insure prompt delivery of vital parts . . . condensers, receivers, welded headers, coils and prefabricated piping.

Write to-day for recommendations.

THE WHITLOCK MANUFACTURING CO.

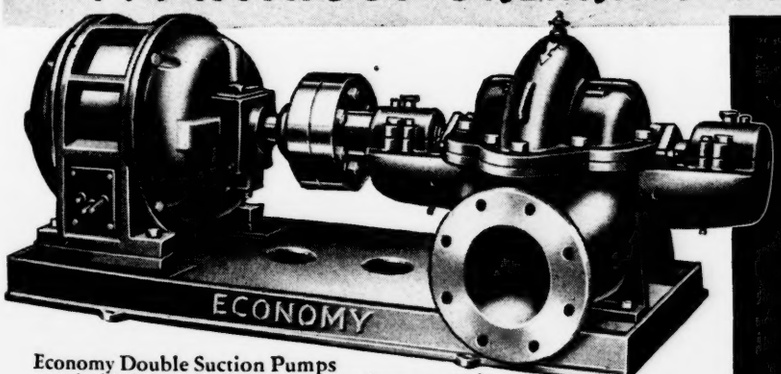
40 South Street, Elmwood, Hartford 1, Conn.

BRANCH OFFICES: NEW YORK, BOSTON, CHICAGO, PHILADELPHIA, DETROIT, RICHMOND.

Authorized representatives in other principal cities—consult local telephone directory under our name.

Whitlock Equipment (Whitlock-Darling) is manufactured in Canada by Darling Brothers, Ltd., Montreal.

QUICK CLEAN-OUT, INSPECTION OR REPAIR . . . WITHOUT BREAKING PIPE CONNECTIONS!



Economy Double Suction Pumps sustain high rated efficiency over a long period of years by virtue of the unusual features engineered into them.

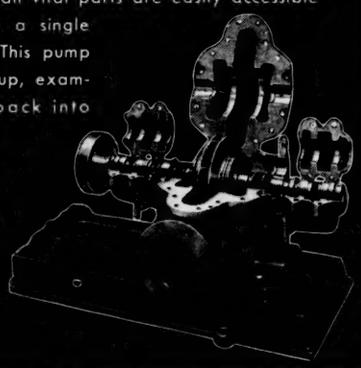
- **Rotor supported between two liberal outboard bearings—giving longer life than is possible with overhung construction.**
- **High efficiency compared with other types, because inlet dia. can be kept small while leakage and friction losses are considerably reduced.**
- **All parts subject to wear are readily removed, without disturbing alignment of unit.**
- **End thrust is almost negligible—thus bearing construction is very much simplified.**

These, and many other Economy advantages, are fully described in free descriptive literature. Write for your copy today.

Special ECONOMY *design features*

PERMIT EASY REMOVAL OF PARTS!

Periodic inspection of pumping equipment is a maintenance "must" today. In the Economy Horizontally Split Case Pump all vital parts are easily accessible without breaking a single pipe connection. This pump can be opened up, examined and put back into service with a minimum of time and effort. Expense due to shutdowns and long delays is thus avoided.



ECONOMY PUMPS, INC.

HAMILTON, OHIO, U. S. A.

(Concluded from page 90)

90% of War Housing Completed

WASHINGTON—With 90% of its scheduled war housing completed, the Federal Public Housing Authority now is concentrating on construction in a comparatively few critical areas and a management job without precedent, according to a report by Herbert Emmerich, retiring Commissioner of the FPHA.

More than 650,000 publicly-financed war housing units have been completed, 68,969 are under construction and 37,039 are in pre-construction and planning stages according to the report. Future construction schedules will be determined by surveys now being made by the National Housing Agency, of which the FPHA is an operating unit.

Sufficient Oil, Standard Oil Executive States

NEW YORK—The fear that this country is on the verge of exhausting its oil resources is needless, Eugene Holman, vice president and a director of the Standard Oil Company of New Jersey, declared April 6 at a meeting of the Chamber of Commerce of the State of New York.

Mr. Holman, former chief petroleum geologist of the company, discussing the general impression that this country is on the verge of running out of oil, asserted that the situation is more reassuring than the alarmists would have the people think.

"It has been said that we have only enough oil in our country to last us fourteen years," he said. He pointed out that this figure is obtained by taking the figure for proved United States reserves, 20 billion barrels, and dividing it by the country's annual consumption, which, he said, is about one and a half billion barrels.

"The trouble with this computation," he said, "is that it ignores several important factors. In the first place, such a computation assumes that no new oil is going to be found in America. The fact is that we are still finding considerable quantities of oil, and geologists agree that there are still huge quantities of undiscovered oil beneath this land of ours.

"It is true that we are not finding new oil at the rate we were finding it before the war, but this is largely a reflection of reduced drilling activities due to wartime shortages of material and labor, and a ceiling price for oil which frequently does not cover the costs of finding oil and recovering it. In other words, we are busy fighting a war, and, as a nation, we do not have time, the tools, the men, and the price-incentive to go wildcatting."

He pointed out also that those who talk about an oil supply limited to fourteen years forget that rarely in the country's history have proved resources been more than fourteen times the annual consumption at that time.

"In 1926 a committee of Cabinet members reported to President Coolidge that the United States had only enough oil to last another seven years," he went on. "In 1919 outstanding geologists proved, to their own satisfaction at least, that only 6 billion barrels of oil remained undiscovered beneath the surface of the United States. Actually we have discovered 48 billion barrels in this country to date."

He stressed the point that technological improvements increased not only the amount of oil found, but the efficiency and effectiveness with which it is used.

"As a matter of fact," he went on, "technology itself undoubtedly already has the answer to supplying us with oil for an almost indefinite future period. Engineers have already demonstrated that we can derive synthetic crude oil at reasonable cost from the great reserves of natural gas and the tremendous deposits of oil shale, of tar sands and of coal and lignite, in the United States and Canada. Conservative estimates place the ultimate amount of oil which can be derived from these sources as sufficient to supply our needs at the present rate for more than a thousand years to come.

"We can continue to lead the way to greater production of oil, to more efficient use of oil and to wider distribution of its benefits. To do this we must have business men of vigor and vision. We must have the intelligent cooperation of our political leaders, and we must have wisdom in our diplomacy. Above all we must have freedom of competition. Wherever there is freedom of action there is competition. Competition is a corollary of freedom, and oil is also a product of competition."

PAW Opens Oil Saving Campaign in Northwest

WASHINGTON—Acting Petroleum Administrator Ralph K. Davies announced April 13 that an oil-to-coal conversion campaign among large industrial fuel oil consumers in the Pacific Northwest must be undertaken immediately to meet rising military demands for fuel oil from West Coast ports.

This action does not affect home-owners and other consumers of distillate fuel oil.

Explaining the necessity for industrial conversions, Mr. Davies said:

"For some time the consumption of industrial (residual) fuel oil in the West Coast—particularly in Washington, Oregon, and Western Idaho—has been in excess of new supply. As a result, steady drafts have been made on existing stocks so that these are now nearly exhausted. Since military requirements for industrial fuel oil in the Pacific theatre of action are increasing, the domestic demand must be substantially lowered.

"Our immediate goal is a 5,000,000-barrel annual reduction, which can be displaced by 1,500,000 tons of coal."

Mr. Davies said that assurance has been received from the Solid Fuels Administration that, even though coal supplies are tight, enough coal can be made available to Washington and Oregon consumers who convert, if these consumers will accumulate stocks during the summer. ODT has assured PAW that transportation will be available to move the coal, and the War Production Board is permitting release of critical materials necessary to convert the heating plants.

George W. Plaisted

SHAKER HEIGHTS, OHIO—George W. Plaisted, 51, vice-president and general sales manager, The Austin Company, died suddenly at his home on April 11.

Mr. Plaisted was a native of Worcester, Mass., and had been associated with The Austin organization since 1916. Since his graduation from the Worcester Polytechnic Institute in 1916, he joined The Austin Co. As a Lieutenant in the Civil Engineer Corps of the Navy during the first world war, he introduced important innovations in dry dock construction at the Puget Sound Navy Yard, and subsequently was public works officer in charge of all maintenance and construction at the Pensacola Naval Station. The company's activities in the Pacific Northwest were launched under his direction when he returned to the company in 1922. He was named vice-president and general sales manager in 1940, and was elected a director in 1941.

He is survived by his widow, a son, a daughter, and two brothers.

HOW MUCH LESS PAPER CAN YOU USE IN YOUR PLANT?

That's a mighty important question. Paper stocks are seriously low this year, and every time another shipload of paper-wrapped war supplies leaves an American port, the problem gets tougher. . . The voluntary cuts, the simple economies you have put into operation up to now, won't be half enough in 1944. . . The only answer is honest, convincing *paper-pinching* by every one who uses paper. . . Organize a Paper Conservation Committee in your company. Pick only the best men for this job, and give them a green light so that they can work effectively. . . From envelopes to heavy cartons, have this Committee see to it that functional packaging is the order of the day—every day. . . In the panel are suggested many ways your plant can use less paper. . . But you know your own business best! . . Go to it *NOW!*

Use Less Paper Because

Multiwall paper bags are used extensively in shipping flour and dehydrated foods.

All openings and exposed surfaces of tanks are sealed with paper for shipping.

Submachine guns are not only paper-wrapped but boxed in paper board. Shell grommets, bomb rings and practice bomb fins are made of paper to save needed steel.

Gas-mask canisters and hand-grenade containers are made of paper.

Paper is used in camouflage strips and netting and parachutes.

All Army clothing and equipment are shipped in waterproof paper wrappers.

Use Less Paper These Ways

Condense letters and memoranda by (a) keeping margins as narrow as possible; (b) sticking to single-space forms; (c) using reverse side of incoming letters as first carbon copy of replies; (d) using reverse side of second sheets for carbon copies; (e) using both sides of all mimeographed sheets.

Check carefully to determine whether your shipping container exceeds the requirements of Rule 41 of "consolidated freight classification requirements."

Eliminate individual cartons in every practical instance.

When individual cartons are indispensable, pack in bulk whenever possible.

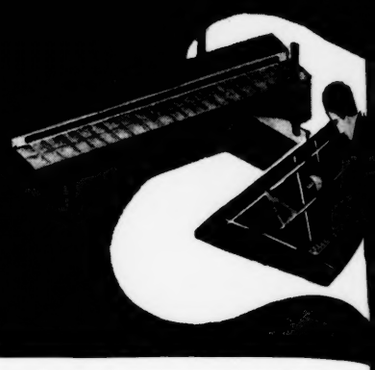
Control disbursement of paper supplies to employees so that excessive quantities do not accumulate in desks and departmental supply closets.

This advertisement prepared under the auspices of the War Advertising Council in co-operation with the Office of War Information and the War Production Board.

LET'S ALL USE LESS PAPER

Space for this advertisement contributed by HEATING AND VENTILATING

REVIEWS



ASHVE GUIDE

The 22nd Edition of the Heating, Ventilating and Air Conditioning *Guide*, dated 1944, has recently appeared. While wartime paper conservation measures have prevented any expansion of the text, it has been possible to add new material by condensing the former guide text without sacrificing essential data. A new chapter dealing with marine ventilation has been added because of the increasing demand for such information.

The tables of heat transmission coefficients in Chapter 4 have been completely revised and rearranged to include values for important materials and constructions not previously listed. Some changes have been made in the chapter on Fundamentals of Heat Transfer in the interest of simplification.

Revised information and tubular data on stratification of air in rooms with high ceilings have been incorporated in the chapter on heat load. Moisture permeability data for various materials have been added to the chapter on cooling load. New data on fuels and the combustion process have been added to Chapter 8. The latest degree-day data compiled by the Weather Bureau, together with new data on predicting residence heat loss, are included in the chapter on estimating fuel consumption.

Chapter 9 on chimneys and draft calculations is largely new, having been brought in line with recent developments, and includes a revised discussion of chimneys for gas heating. Chapter 10, dealing with automatic fuel burning equipment, has been extensively revised.

The chapter on pipe, fittings and welding contains entirely new data on commercial pipe dimensions as well as current information on threading practice. Chapters 24, cooling, dehumidification and dehydration, and 27, spray equipment, have been thoroughly revised. Revisions and additions to Chapter 33, sound control, involve changes in the data on fan noises, clarifying the information on elbow attenuation and amplifying the data on absorption for plate cells. Chapter 34, automatic control, has been rewritten.

State code references in Chapter 48 have been corrected to 1944. Chapter 49 is a new chapter on marine heating and ventilating and contains essential information of the design and ventilating systems for ships.

Size 6¼ x 9¼, cloth bound, published by American Society of Heating and Ventilating Engineers, 51 Madison Ave., New York, N. Y. Price $5 per copy. The book contains 1168 pages of text and 104 pages of other information.

AMERICAN HOUSING

American postwar demand for housing probably will exceed 1,000,000 units per year for the first ten years after the firing stops. Employment and production in the home construction and related industries should reach levels in excess of anything accomplished in the past.

These are part of the findings in the book "American Housing—Problems and Prospects," by Miles L. Colean. The author states that $6,000,000,000 may be spent annually for housing construction during the postwar period. He states:

"In the postwar period, the competition among materials, for which excess capacity will have been created, promises to add new impetus to these developments. Steel, aluminum, magnesium and plastics are all likely to play new roles in housebuilding."

Size, 6x9 in., cloth bound, 466 pages. Published by The Twentieth Century Fund, 330 West 42nd St., New York 18, N. Y. Price, $3.

BRIEF REVIEWS

HEAT TRANSFER—A paper presented before the American Society of Mechanical Engineers entitled "The Influence of Through Metal on the Heat Loss from Insulated Walls," by Victor Paschkis and Michael P. Heisler, Columbia University. Paper is a study of the heat flow through such a structure as an insulated ship hull which is considerably larger than would be found from adding to the heat flow through the insulation that contributed by the "through" metal as if the two were independent. The paper represents studies on the electrical analogy system in use at Columbia. The paper was contributed to the heat transfer division meeting and presented at Birmingham April 3-5. Available from the ASME.

AIR FLOW—In a paper "Resistance of Soybeans and Oats to Air Flow," by S. Milton Henderson in the April, 1944, issue of *Agricultural Engineering*, results are given of a study to determine the resistance of stored soybeans and oats to air flow. Data are also given on the rate of air flow through various grains for a few air pressures. Figures are also given on the resistance to air flow of perforated steel sheets covered with soybeans, oats, and grain.

HYDROGENATION—Report No. 1 of a series on hydrogenation of coal at high temperatures, by J. L. Bray and R. E. Howard, both of the School of Chemical and Metallurgical Engineering, Purdue University, Lafayette, Ind. The booklet contains 55 pages, paper covered, 6 x 9 in. in size, available to residents of Indiana without charge; limited number of copies available to non-residents without charge, otherwise 25c.

CHECK VALVES—A report covering an investigation of the loss of head involved in the flow of fluids through small swing-check valves, Engineering Experiment Station report No. 88 entitled "Flow of Water Through Small Swing-Check Valves", by F. W. Greve and W. C. Killin, both of the School of Civil Engineering, Purdue University, Lafayette, Ind. Size 6 x 9 in., 20 pages, paper covered, available to residents of Indiana without charge; limited number of copies available to non-residents without charge, otherwise 15c.

FLOOR FURNACES—Commercial Standard CS-113-44, covering oil-burning floor furnaces equipped with vaporizing pot-type burners. Available from Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. Price, 10c.

WELDING—An 89-page bulletin, 6 x 9 in., heavy paper bound, entitled "Guide to Weldability of Steels", and published by the American Welding Society, 33 W. 39th St., New York 18, N. Y.

VALUATIONS — A 12-page standard bulletin entitled "Valuations, Appraisals, Inventories", issued by Ford, Bacon & Davis, Inc., 39 Broadway, New York, N. Y.

FEATHER VALVE AIR COMPRESSORS

Worthington Pump and Machinery Corporation, Harrison, N. J.

The various models of feather valve air compressors are illustrated and described in a 4-page bulletin H-620-B21C. Engineering data on the various types are presented in tabular form.

DEGASIFICATION OF WATER

Cochrane Corporation, 17th and Allegheny Ave., Philadelphia 32, Pa.

Bulletin 4076 illustrates equipment that is available for the removal of gases from water at various temperatures. It also shows means for removing oxygen and carbon dioxide from water without using steam.

NON-CONDENSIBLE GAS PURGERS

Armstrong Machine Works, Three Rivers, Mich.

This company's non-condensible gas purger for removing air and other non-condensibles from refrigerating systems, is described in an 8-page bulletin just released. It describes the operating principles and presents installation diagrams and photographs.

TURBINE VENTILATORS

The Allen Corporation, 9751 Erwin Ave., Detroit 13, Mich.

New literature has been made available to show the line of ventilating equipment manufactured by The Allen Corporation. Turbine ventilators are shown in simple diagrammatic form and the principles of operation described. A table shows the rated displacement capacity of various sized units.

PIPING

Crane Co., 836 S. Michigan Ave., Chicago 5, Ill.

A 32-page standard size bulletin entitled "Piping Pointers for Industrial Maintenance Men," and giving definitions of various terms used in piping, explanation of service rating marks, common types of end connections, a discussion of various valve designs and how they operate, range of pipe fittings, hints on handling valves, fittings and pipe, suggestions for proper installation of pipe and fittings including a page each on how to make up a screwed joint and how to make up a flanged joint, recommended procedure for making up a solder-joint, a brief description of welded pipe joints, instructions on installing globe valves, what to do when valves leak, repairing and maintenance of valves and fittings, and information on planning.

ROTARY SHEARS

Kling Bros. Engineering Works, 1308 N. Kostner Ave., Chicago 51, Ill.

The six sizes of rotary shears made by this company are illustrated and described in an 8-page bulletin No. 245. The largest machine will shear sheets or plates up to 1 in. thickness. These machines will also cut or form a large variety of shapes.

GAUGES

Manning, Maxwell & Moore, Inc., Bridgeport 2, Conn.

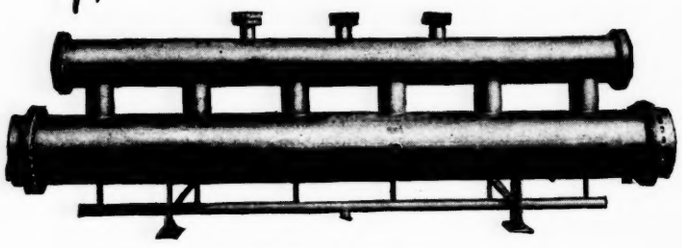
A 12-page, standard size bulletin devoted to the phenol turret case Duragauge. Booklet illustrates in colors assembly of the gauge, explains the rotary movement, design and construction of the system, and gives dimensional drawings and illustrations.

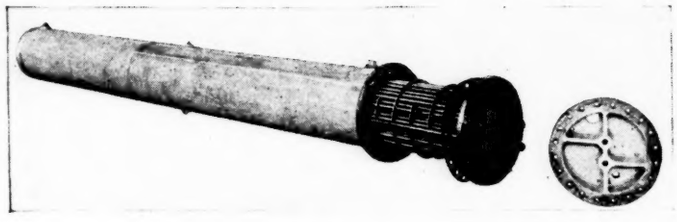
(Continued on page 96)

ACHIEVEMENT
ARMY
E
NAVY
that challenges
future effort
Promises are just promises unless kept; but performance is history. That's why we are proud of our Army-Navy "E" award. It expresses Uncle Sam's recognition of our contribution to this nation's production record . . . a performance that will live in history. As such, our "E" is not only a symbol of a vital job well done but an inspiring challenge to the men and women of General Controls. ★ We pledge ourselves to continue giving our best, and more, to produce Automatic Controls for America's needs. Today, tomorrow and until "V" Day, we will continue to earn our "E" by performance.
hi-g
GENERAL CONTROLS
Wartime Manufacturers of Electro-Magnetic and Temperature Controls for Aircraft
Peacetime Manufacturers of Automatic Pressure Temperature, and Flow Controls
801 ALLEN AVENUE, GLENDALE 1, CALIFORNIA
BOSTON • NEW YORK • PHILADELPHIA • DETROIT • CHICAGO
CLEVELAND • DALLAS • DENVER • SAN FRANCISCO • ATLANTA

Typifying
PATTERSON-KELLEY
Service and Products

FREON COOLERS
BRINE COOLERS
AMMONIA COOLERS





This is an engineering specialty in itself...a specialty that calls for an understanding not only of heat transfer phenomena but of refrigerants and their behavior. Calculations are not as simple as $2 + 2 = 4$.

That Patterson-Kelley is looked upon as specialists in this field is evidenced by the many "coolers" provided for refrigerating and air-conditioning systems throughout the country.

If you have any problem along these lines, or are working on some project, we would like to help.

EST. 1880
THE PATTERSON-KELLEY Company, Inc.
Main Office and Factory
122 WARREN STREET, EAST STROUDSBURG, PA.
BOSTON 16, 96-A Huntington Avenue • NEW YORK 17, 101 Park Avenue
PHILADELPHIA 3, 1700 Walnut Street • CHICAGO 4, Railway Exchange Building

CENTRAL HEATING

The Ric-wiL Company, Cleveland, Ohio

A standard size, 6-page folder urging serious consideration to central or group heating as a service for communities or groups of buildings. Includes numerous photographs of communities and projects so heated together with text describing the advantages of this method coupled with information on the company's distribution lines.

THERMOCOUPLES

Wheelco Instruments Co., Harrison and Peoria Sts., Chicago 7, Ill.

A new edition of the company's Thermocouple Data Book and Catalog, bulletin S2-4, containing 36 pages. Catalog gives a description of products, prices and recommendations for thermocouple users, and suggests substitutes for restricted materials. It carries the latest amendment to the WPB's Conservation Order L-134, and gives data in selection of thermocouples, lead wire, protecting tubes, heads and insulators. Also carried are temperature conversion tables, millivolt tables, and tables on pipe and wire sizes, decimal equivalents and wire resistances. Instructions are given on checking thermocouples and pyrometers, and on construction of thermocouples.

V-BELTS

Allis-Chalmers Mfg. Co., Milwaukee 1, Wis.

A 44-page Bulletin B6249 describing the line of fractional horsepower Texrope V-belts and sheaves. Offers simplified engineering data for fractional horsepower drives. Horsepower ratings are based on driven revolutions per minute and on belt velocity. Also included in the new book are working formulas from which correctly-engineered fractional horsepower drives can easily be derived. Amply illustrated with installation photographs, line drawings and selection tables, the bulletin will be of interest to manufacturers and operators of light duty power tools, fans, blowers, pumps, stokers, oil burners, processing equipment, numerous appliances.

AIR CONDITIONING

Carrier Corp., Syracuse 1, N. Y.

Condensed catalog AC-161, on air conditioning, refrigeration, and space heating, 12 pages, standard size. Information is presented in concise hand-book style for quick reference in selecting air conditioning apparatus and related equipment to perform a required function efficiently and economically. Sections are: air conditioning, air distributing systems, refrigeration, and industrial heating and ventilating.

FEEDWATER REGULATORS

Northern Equipment Co., 1945 Grove Drive, Erie, Pa.

The sixth edition of the 28-page booklet "Mechanical Feed Water Regulation for Boilers," by Professor E. P. Culver. Booklet covers the principles of boiler feed water control, and describes mechanical equipment available to meet various operating conditions. Differential pressure control and feed pump control are also discussed. Contains numerous illustrations, diagrams, and chart reproductions.

ION-EXCHANGE PROCESS

Worthington Pump and Machinery Corporation, Harrison, N. J.

The purification of water in the ion-exchange process which employs a granular insoluble material as an exchanger for hardness, is described in bulletin W-212-B4. A double-unit ion-exchanger is illustrated and the various features of this process are described.

WATER TREATMENT

Calgon, Inc., Hagan Building, Pittsburgh, Pa.

A 12-page folder entitled "Micromet for Scale Prevention Corrosion Control" and dealing with the scale and corrosion problem and how it can be solved by using Micromet in the water in heating systems, air conditioning units, and evaporative condensers.

CONTINUOUS BLOW-OFF SYSTEMS

Cochrane Corporation, 17th and Allegheny Ave., Philadelphia 32, Pa.

The heat saving that can be obtained by the use of the continuous blow-off system is described and illustrated in bulletin 4081. Equipment available for different heat balance requirements is shown.

Getting Personal

C. P. Stolberg

Cornell University is represented in this feature column. **C. P. Stolberg** (Detinning Plant Uses 20,000 Feet Pipe, page 41) is a Cornell grad, Class of 1931.

He has been employed on mechanical engineering work by the J. G. White Engineering Corp., New York, The Austin Company, and in later years by The H. K. Ferguson Co.

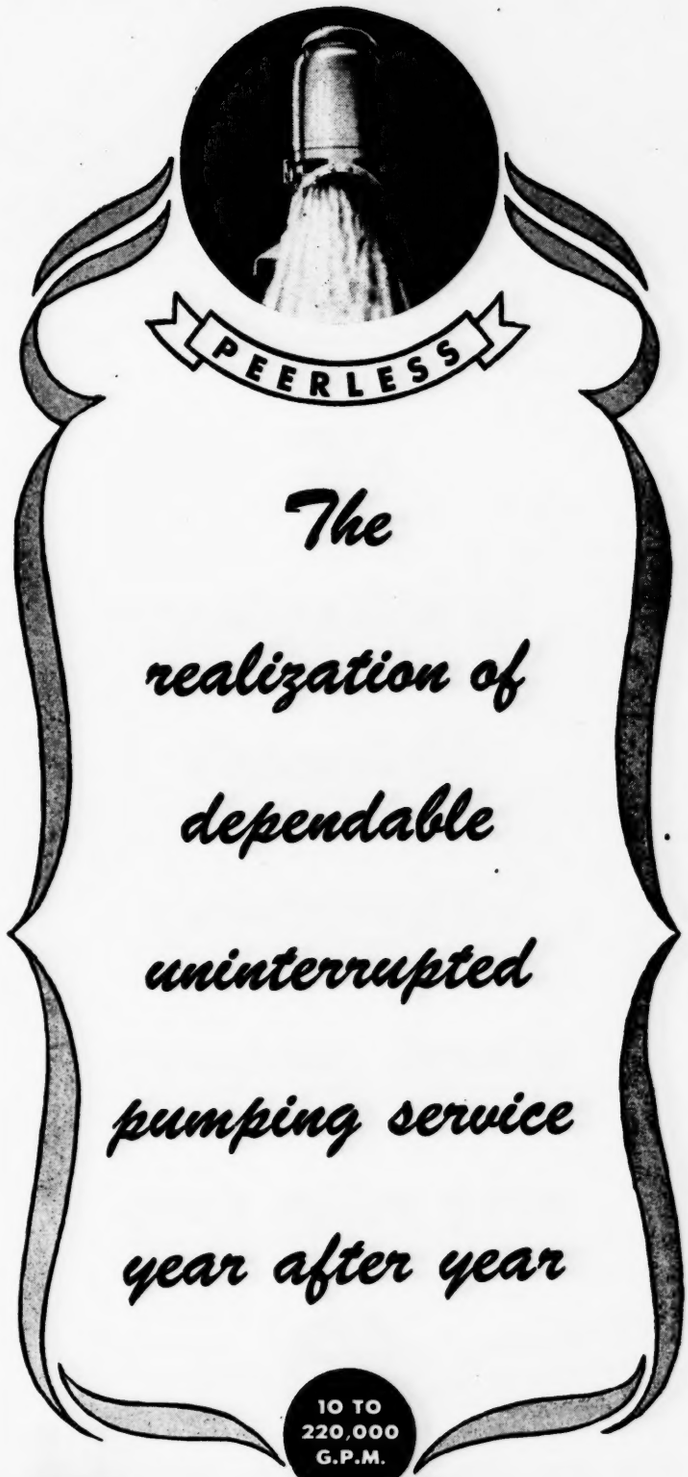
Mr. Stolberg has been associated with the design of power houses, chlorine generating plants, and chemical plants for the Chemical Welfare Service, Defense Plant Corp., and private industry. He served as Assistant Project Engineer on the detinning plant job described in the article.

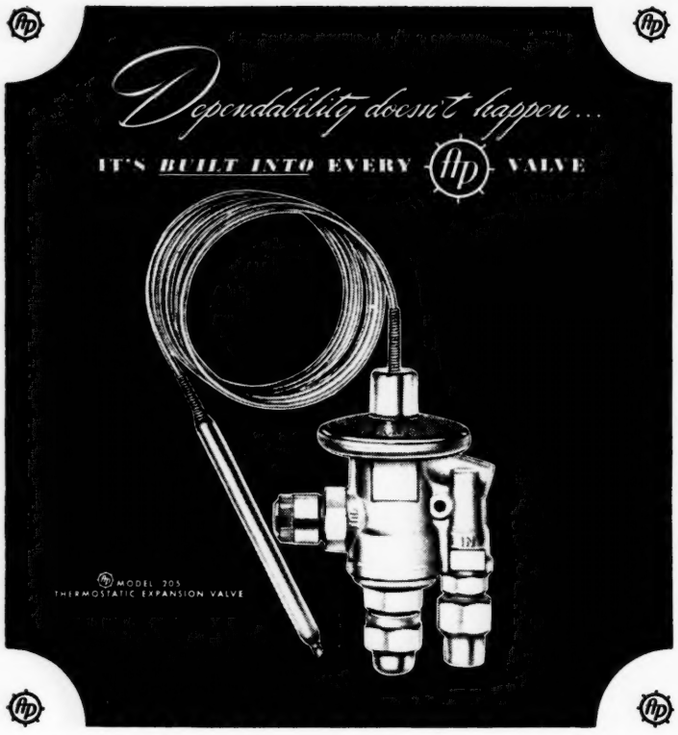
F. Keller

F. Keller (Refrigeration of Aluminum Alloys Retards Age Hardening, page 49) is at present chief of the Metallography Division, Aluminum Research Laboratories. He received his technical education at Brooklyn Polytechnic Institute and University of Pittsburgh.

From 1917 to 1926, he was metallurgist, Aeromarine Plane & Motor Co., Keyport, N. J. Since then, he has been with Aluminum Research Laboratories working on development of metallographic methods. He has been granted 18 U. S. Patents on alloys and processes and has written 25 or more technical papers and articles on many phases of the metallography and metallurgy of aluminum alloys. The original experiments on the practical application of refrigeration in retarding age hardening, which form the background for the present article, were conducted by the author in 1931.

Are we perturbed! In the March issue, we called attention to the fact that **A. J. Mallinckrodt** (Refrigeration Insures Quality of Clothing for the Army) was one engineer who reversed the famous advice of Horace Greeley, and moved east. Mr. Mallinckrodt has since moved west and is now with the Baker Ice Machine Co., Omaha, Neb.


PEERLESS
The realization of dependable uninterrupted pumping service year after year
10 TO 220,000 G.P.M.
Peerless Pumps
TURBINE • HI-LIFT • HYDRO-FOIL
PEERLESS PUMP DIVISION, Food Machinery Corporation
301 W. Ave. 26, Los Angeles 31, California
1250 W. Camden Ave., S.W., Canton 6, Ohio
OTHER FACTORIES: San Jose 5, and Fresno 16, California



A-P MODEL 205 THERMOSTATIC EXPANSION VALVE

• To the owner and operator of air conditioning systems and small refrigeration units, the A-P Model 205 Thermostatic Expansion Valve offers many benefits. Its recognized DEPENDABILITY in long, service-free operation, its accurate, supersensitive refrigerant-control are important factors in maintaining the efficiency of your system, with a minimum of service expense.

• Be sure to install the Model 205 on every air conditioning unit up to two tons Freon capacity, or on refrigerated display cases, room coolers, ice cream cabinets or other refrigeration systems requiring DEPENDABLE refrigerant control up to one ton Freon capacity.

AUTOMATIC PRODUCTS COMPANY
2462 North Thirty-Second Street, Milwaukee 10, Wisconsin

DEPENDABLE REFRIGERANT VALVES

STOCKED AND SOLD BY PROGRESSIVE REFRIGERATION JOBBERS EVERYWHERE. RECOMMENDED AND INSTALLED BY LEADING REFRIGERATION SERVICE ENGINEERS.

WITH THE MANUFACTURERS

BARBER-COLMAN CO.

Rockford, Ill., has appointed D. J. Stewart, previously assistant general manager, vice-president and general manager, succeeding Earle D. Parker. H. F. Collins, former assistant general superintendent, has been appointed works manager.

MINNEAPOLIS–HONEYWELL REGULATOR CO.

has appointed two new branch managers and two supervisors. Kentner L. Wilson, previously industrial manager of the Cleveland office, was promoted to branch manager of the Detroit district. Charles Locke, formerly branch manager at Albany, and for the past two years attached to the Production Department at the main plant, has become branch manager of the Indianapolis office. D. J. Peterson, who has been acting as branch manager at Detroit, has been promoted to zone original equipment supervisor, and now is in charge of all original equipment activities in the Cleveland Zone. Temporarily, his headquarters will be in Detroit. In Indianapolis, Edward Clucas, who has been acting branch manager, will hereafter be in charge of the company's Modutrol Division activities in that district.

THE MARLEY COMPANY, INC.

Kansas City, Kansas, is now represented in the Tulsa area (all of Oklahoma, western Arkansas and the Texas panhandle) by Walter S. Smith and his Process Equipment Company, 306 Tulsa Building. Mr. Smith, a resident of Tulsa for more than six years, is well-known throughout the territory as an applications engineer for heat transfer equipment.

Walter S. Smith

From the main office, Joe T. McKinley has joined the Houston staff. The Kansas and western Missouri area is now handled by R. H. Ahrens out of the company's headquarters at Kansas City.

THE MERCOID CORPORATION

has moved its New York office to 205 E. 42nd St., New York 17, N. Y. R. Fenton Fisher is vice-president in charge.

U. S. MACHINE CORP.

Lebanon, Ind., has announced appointment of Electrol Oil Burner Corp., Seattle, Wash., as distributor of Winkler stokers for certain territories in Oregon and Washington west of the Cascade mountains, and for British Columbia and Alaska. Heading the Electrol firm is Robert Denny Watt, president and son of its founder, the late Paul H. Watt.

FITZGIBBONS BOILER COMPANY, INC.

has assigned two groups of production and sales engineers to the task of analyzing the post-war prospects of the company. The post-war production planning committee, headed by Ray C. Malvin, general plant manager and recently appointed vice-president, is devoting its time to the designing and modernization of the company's heating equipment. At the same time the post-war sales planning committee, under the guidance of O. F. Noss, assistant sales manager, is studying post-war markets for the company.

CARRIER CORPORATION

has announced that R. L. Tomlinson, for 21 years manager of the Marine Department, Carrier Corporation, has resigned because of ill health. Leo Starr and J. R. Lewis, of the Marine Department, have been appointed to the posts of Sales Manager and Operations Manager of the department, respectively. Mr. Starr has been with Carrier for 21 years, while Mr. Lewis joined the company in 1931. James A. Bentley, vice-president, will direct affairs of the Marine Department in addition to continuing his present responsibilities.

PERSONALS AND PERSONNEL

E. H. MINTIE

E. H. Mintie

has been appointed by Air-Maze Corporation as factory representative and field engineer for California and Arizona, with headquarters in Los Angeles, succeeding E. B. Treidler who has resigned.

Mr. Mintie, a graduate mechanical engineer, is a native Californian and has been engaged in engineering, design and sales work in that area for the past twenty years.

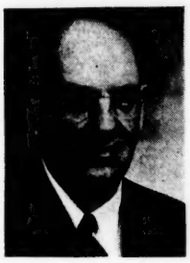
FRANK E. WALBRIDGE

has been named supervisor of refrigeration control sales for the Cleveland zone of Minneapolis-Honeywell Regulator Co. His territory comprises Ohio, Northern Kentucky, West Virginia, Western Pennsylvania, Western New York and Michigan. Mr. Walbridge started with Minneapolis-Honeywell in 1936 as retail salesman in Cleveland. His new assignment became effective April 1.

T. S. PENDERGAST

has resumed his post as vice-president in charge of sales at Universal Cooler Corp., Marion, Ohio, from which he was given a leave of absence to expedite war production in the company's plant.

VICTOR LAZO



Victor Lazo

has been appointed sales manager by York-Shipley, Inc., York, Pa. Mr. Lazo was for many years sales manager of Pierce-Phelps, Inc., Philadelphia, heating equipment distributors. Plans for post-war expansion by York Heat are proceeding systematically under Mr. Lazo's supervision. At his previous position he directed the sale of units in three states.

CARL F. BOESTER

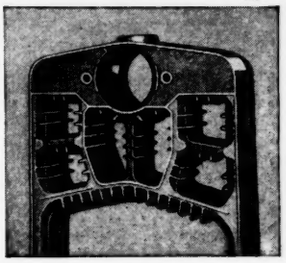
housing research director of the Purdue Research Foundation has been chosen as one of the ten outstanding young men of 1943 by *Future* magazine, official publication of the United States Junior Chamber of Commerce. Mr. Boester has been with Purdue for four years supervising housing research to stimulate and initiate low cost housing through facilities provided by the university. He has been active in heating, ventilating and air conditioning work for a number of years and is a member of the ASHVE committee on research.

JOHN A. SCHENK

Alco Valve Co., St. Louis, former Chicago district manager has been appointed application engineer. For the last two years he has handled priority material allotments and production coordination at the St. Louis plant. His duties will embrace problems of design and application encountered by users of Alco products. Mr. Schenk has been with Alco since January, 1935. After spending a year in the engineering department on research and design, he managed the company's Chicago office until it was closed by the war in April, 1942. He is a member of the A.S.R.E., and active in refrigeration circles throughout the Chicago and St. Louis areas.

(Concluded on page 100)

NATIONAL N·R RADIATOR features



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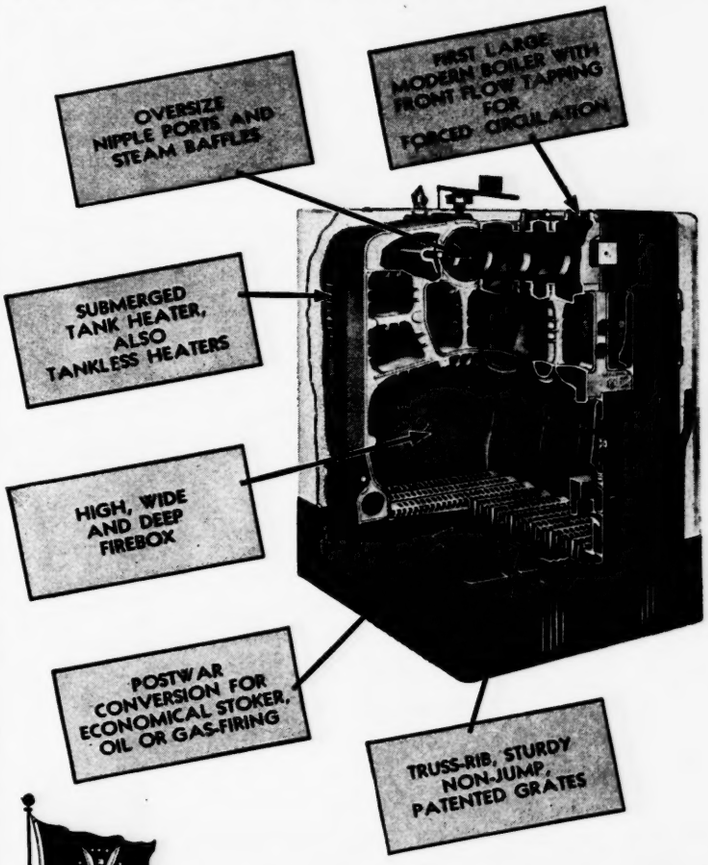
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